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CONTENTS

THE 1958 VISCOUNT NUFFIELD PAPER

"The Production, Fabrication, Properties and Uses of Some of the Newer Metals" by Dr. N. P. Inglis 219

Report and Discussion 238

THE 1959 NORTH WESTERN REGIONAL PAPER

"The Problems of Productivity in the Cotton Textile Industry" by Allan Ormerod, J.P., A.I.Mech.E., A.M.I.Prod.E., A.M.C.T. 245

"A British Viewpoint on International Standards" by H. A. R. Binney, C.B. 264

"Can Work Study Benefit Small Factories?" by H. H. Hoch, Dipl.-Ing., M.I.Prod.E., A.F.A.I.M. 269

Council Nominations — 1959 - 1960 282

Institution Notes 283

News of Members 284

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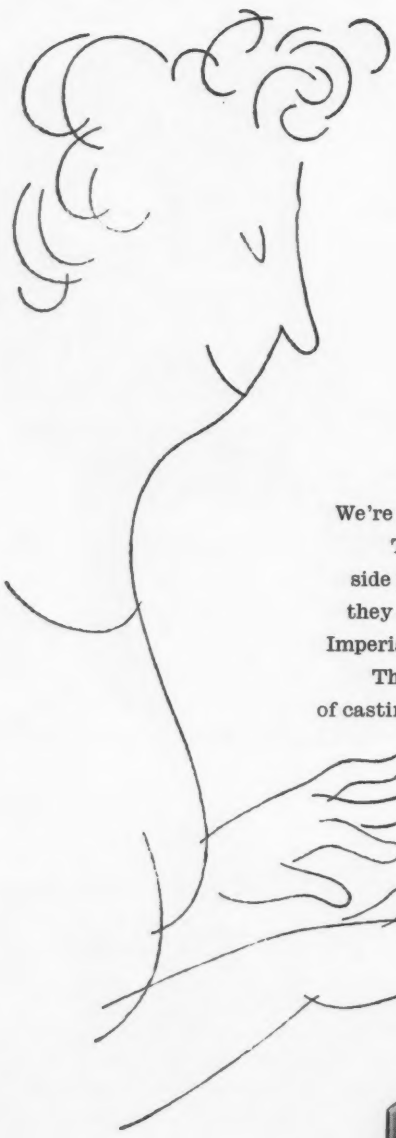

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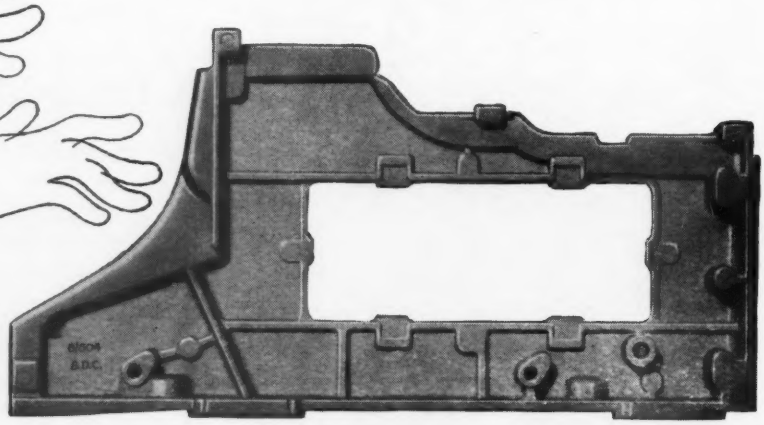

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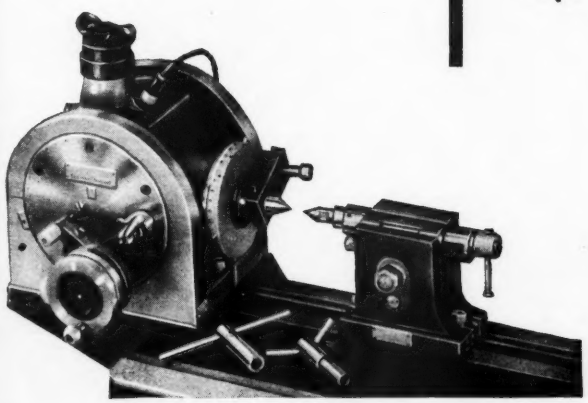

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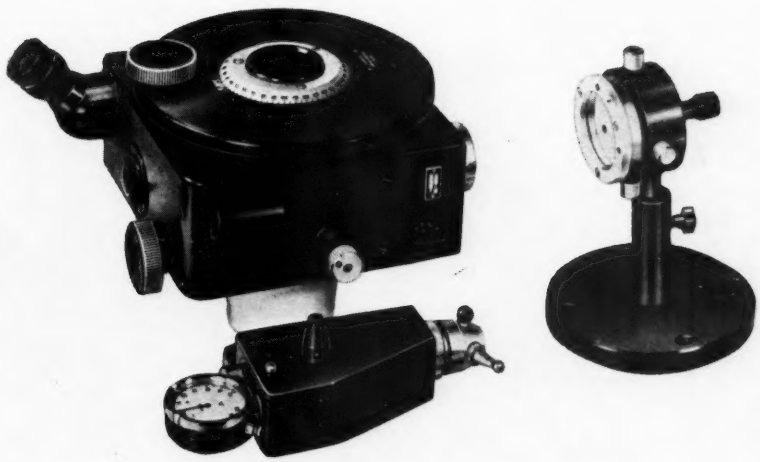

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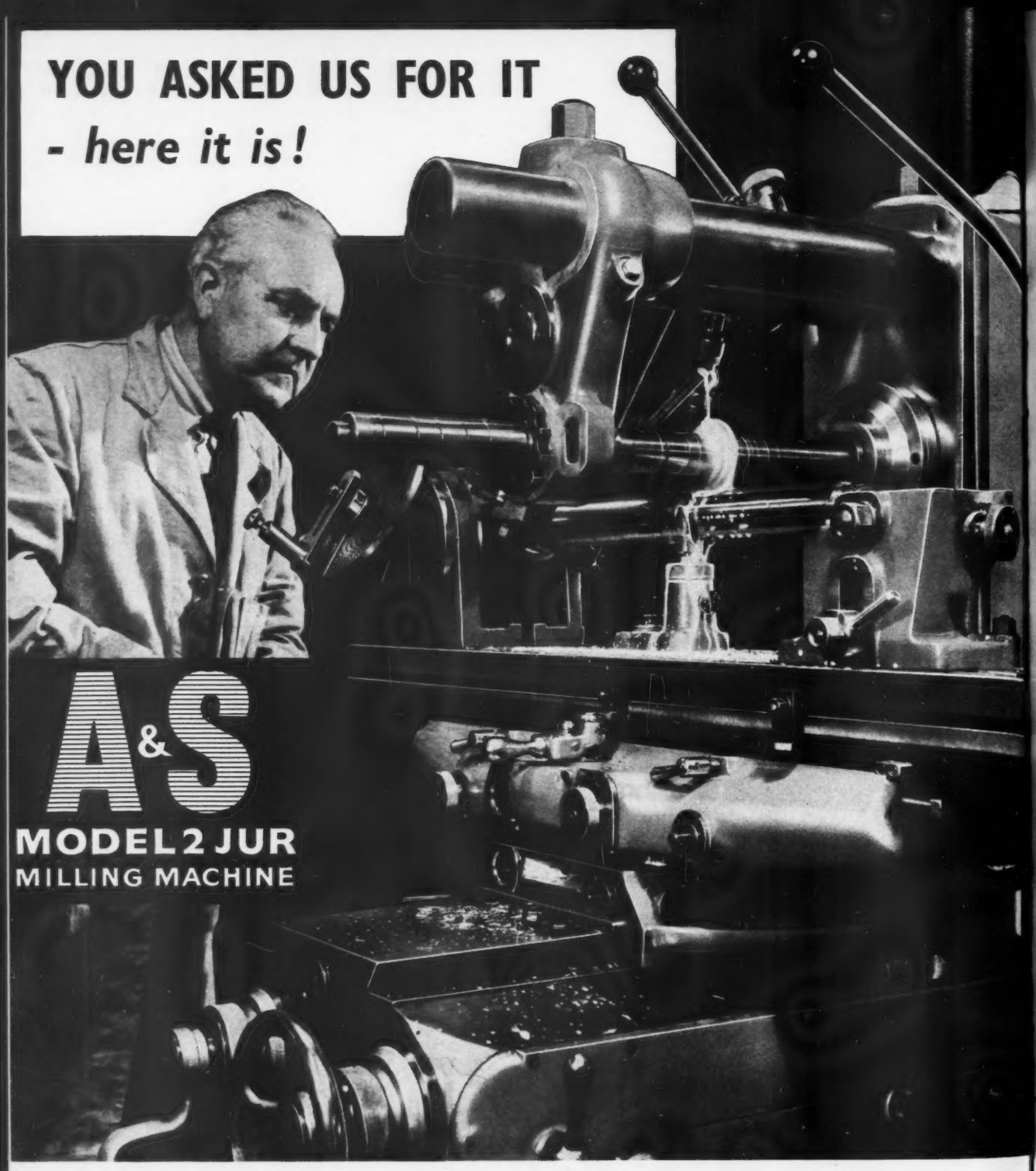

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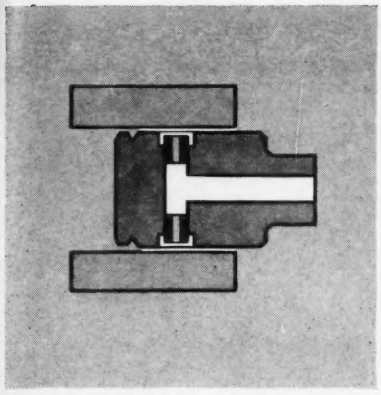

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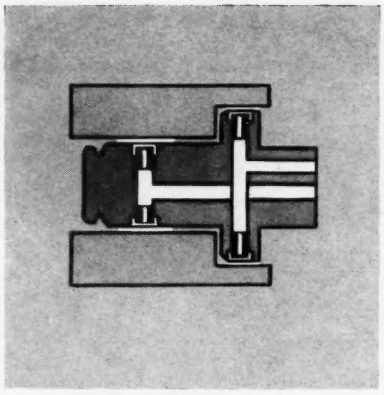
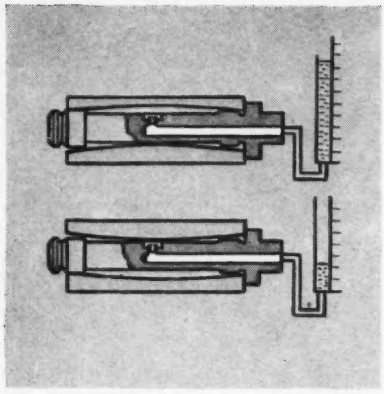


Two-dimensional non-contact air jet plug gauge



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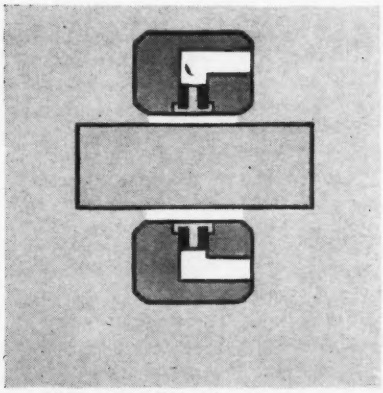

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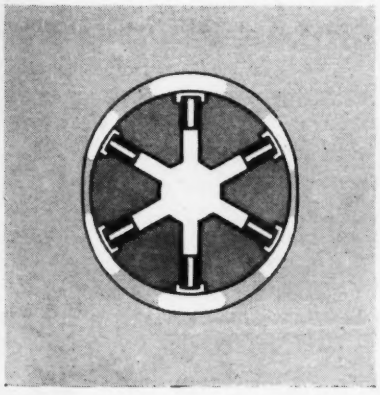
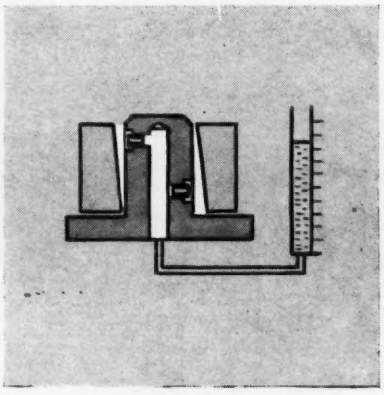
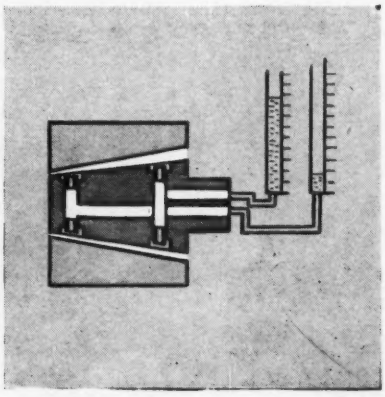


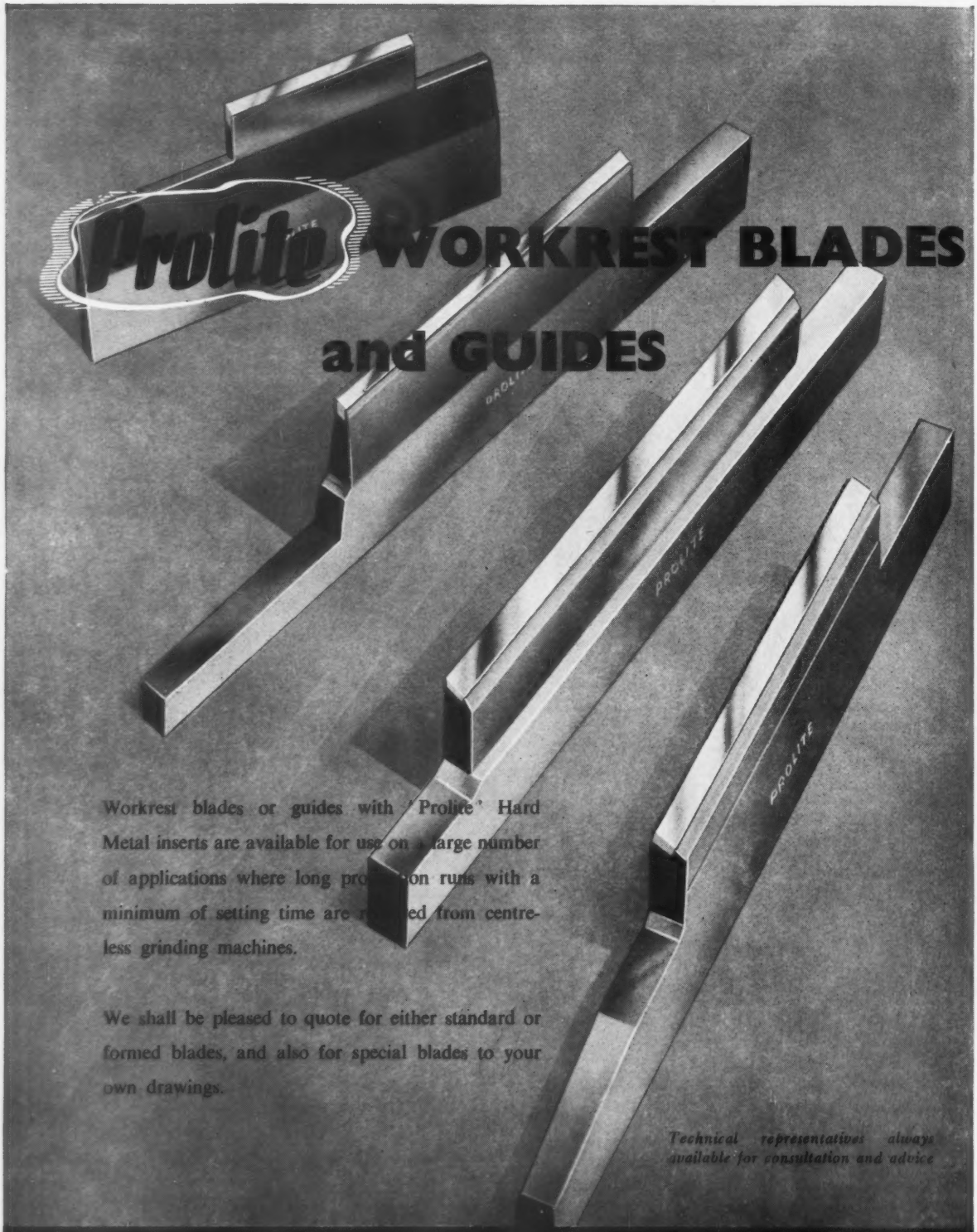
Average diameter non-contact air jet plug gauge



Determination of squareness of bore to face—with air jet gauge



Measurement of angle—tapered bore—with air jet gauge



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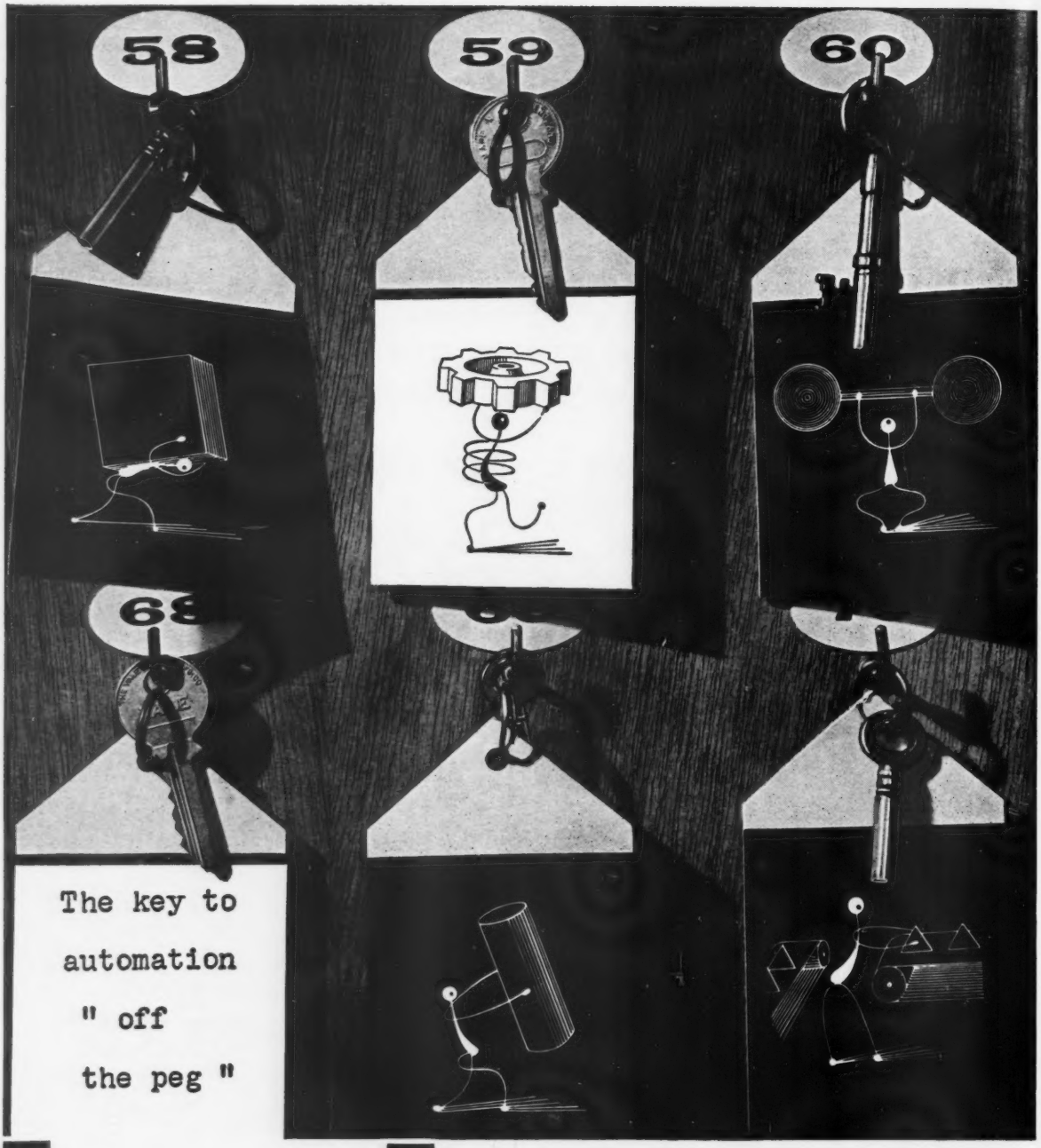

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Automation

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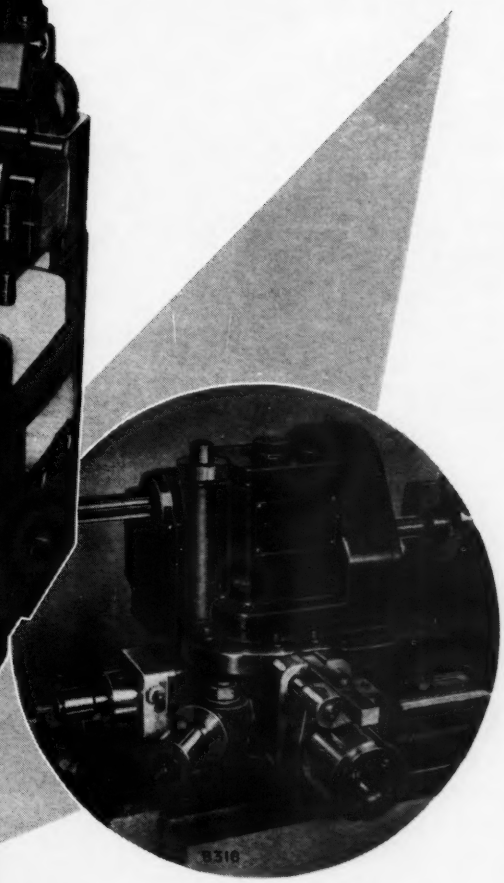

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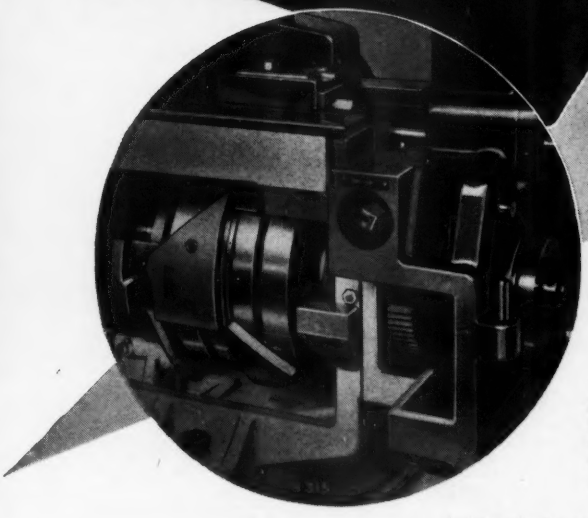

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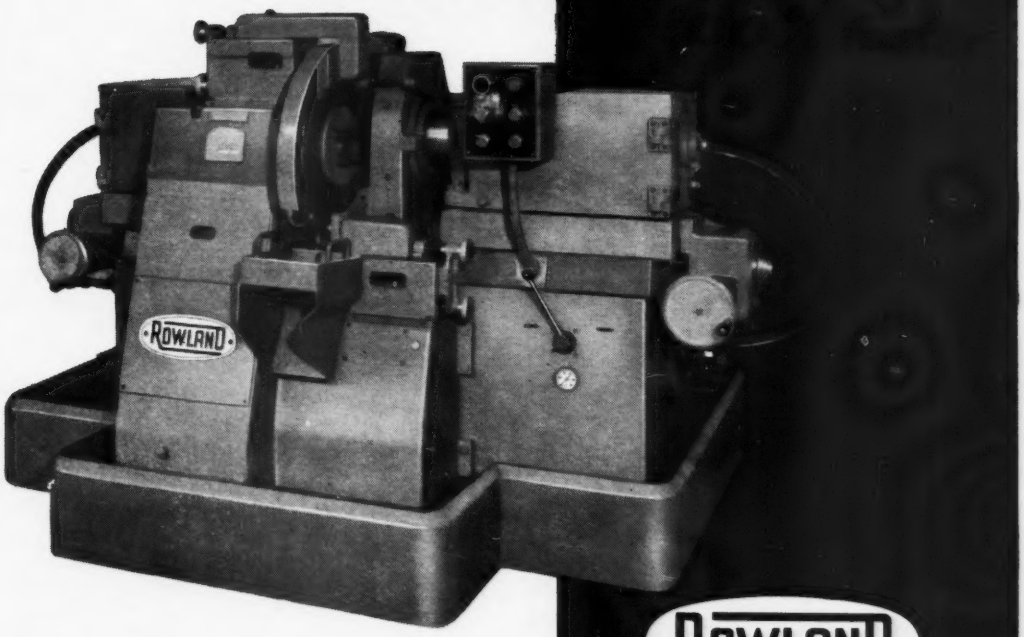

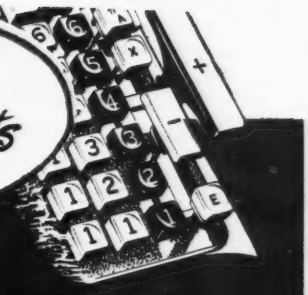

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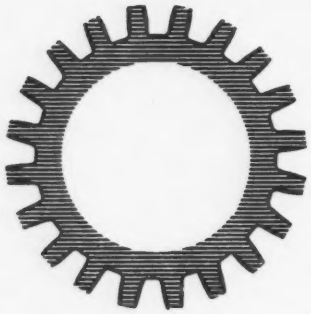

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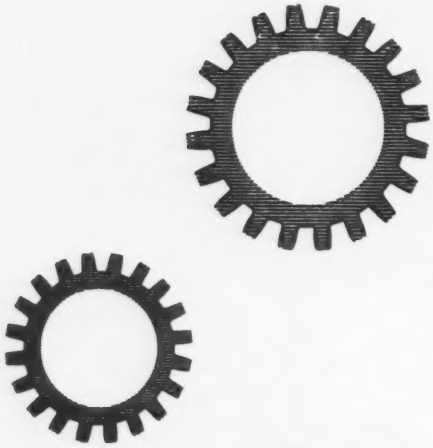

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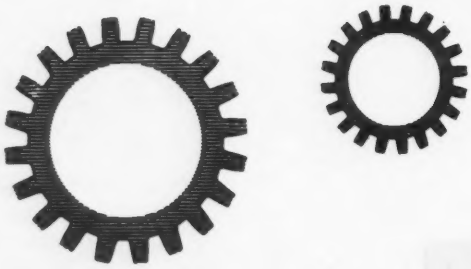

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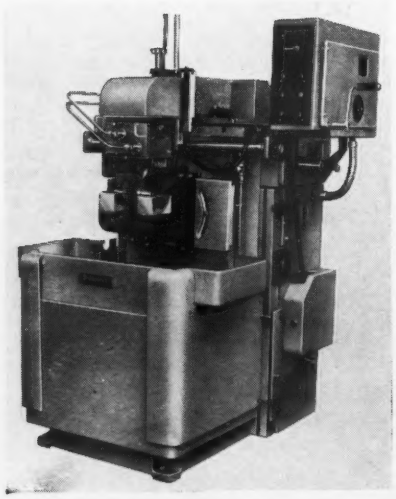

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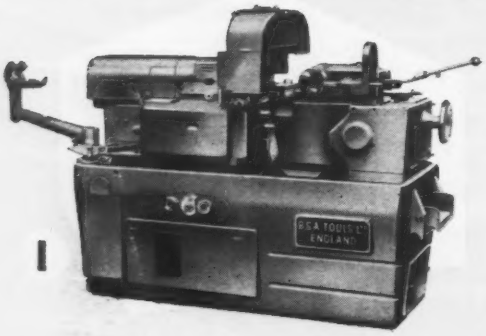

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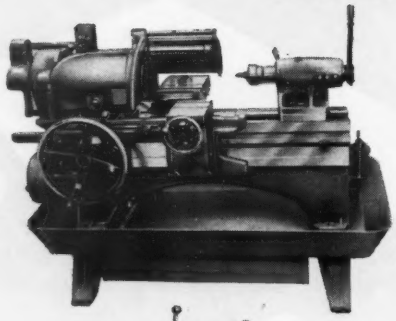

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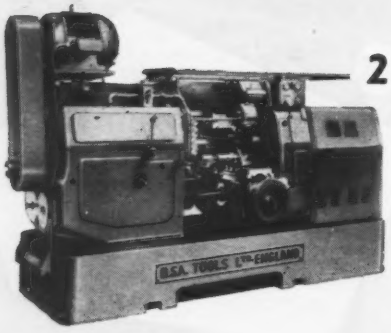

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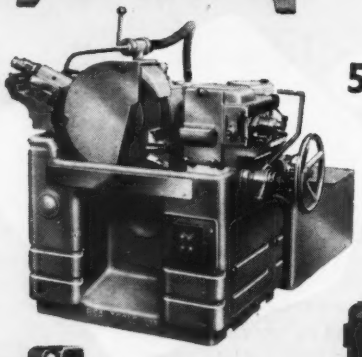

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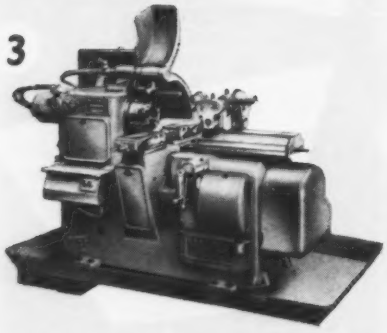

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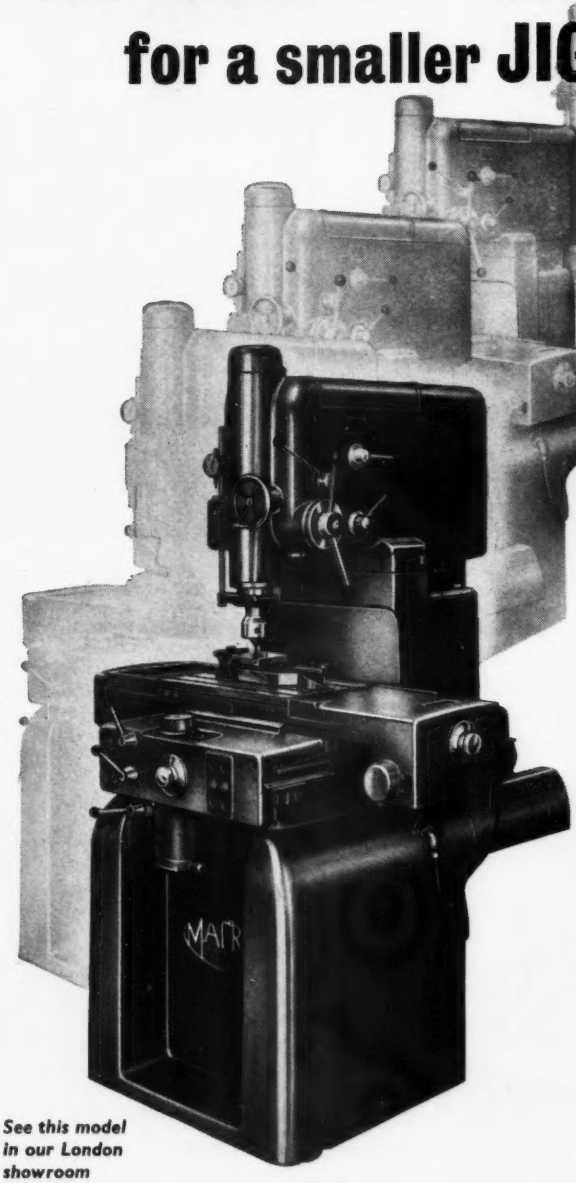

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The MATRIX No. 59 Jig Boring Machine is built to the highest standard of accuracy and specially designed for easy operation.

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Infinitely variable spindle speeds from 100 to 3000 rpm are simply selected by rotating switch.

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Table surface	18″ x 12″
Table travel	12″ x 8″
Max/min. distance from spindle nose to table surface	22/2½″
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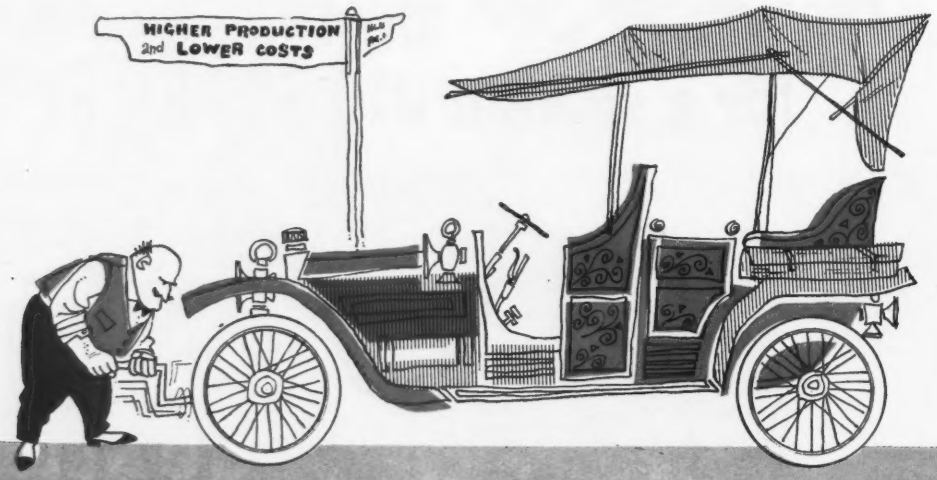

for competitive performance, today

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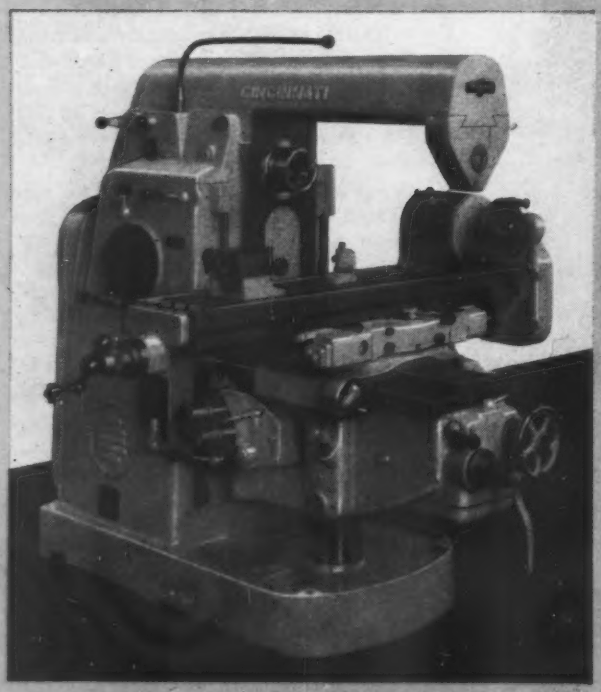

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C4/59 CINCINNATI MILLING MACHINES LIMITED, Birmingham 24

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A typical installation for pressure vessel and similar work incorporating a LINCOLNWELD B.10 Fully Automatic Submerged Arc Welding Head, the LINCOLN L.R.C. Revolving Column and Travelling Boom and LINCOLN L.S.A.R. Self-Aligning Variable Speed Rotators.

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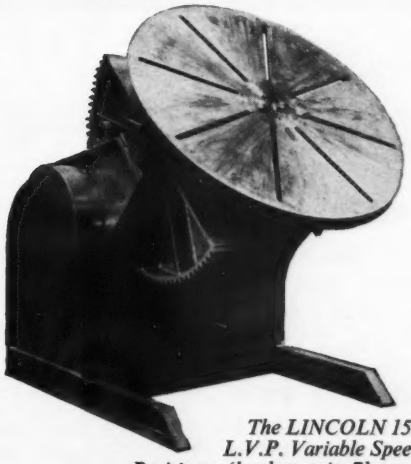

The LINCOLN 150 L.V.P. Variable Speed Positioner (load capacity 7½ tons)

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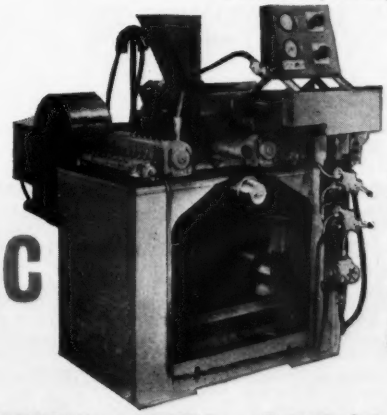

A LINCOLN Seam Welding Machine, incorporating the LINCOLNWELD M.L.3. Remote Control Automatic Submerged Arc Welding Unit.

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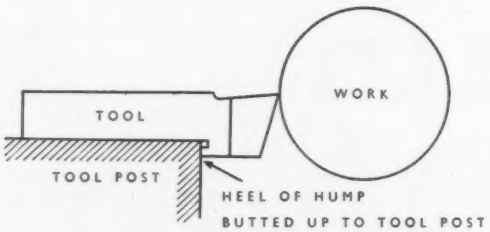
P6

The Stag Athyweld Hump-Backed Parting-off tool tipped with 10 - 12% Cobalt high speed steel.

"STRENGTH in what remains behind"

(Wordsworth)



The Stag Athyweld deposit welding process with its complete metallurgical control has made possible a new design of hump-backed parting-off tool with increased strength and resistance to fracture.

Deepening the section of the blade to approximately one and a half times the depth of the section and anchoring it to a supporting section considerably increases resistance to cutting forces.

These Athyweld 10 - 12% Co. super high speed tools, although somewhat commonplace to look at, have been very carefully designed from a welding point of view. Design for welding is a most important feature.

Edgar Allen & Co. Limited should be consulted in the design stage by customers wishing them to make special tools by the Athyweld patent welding process.

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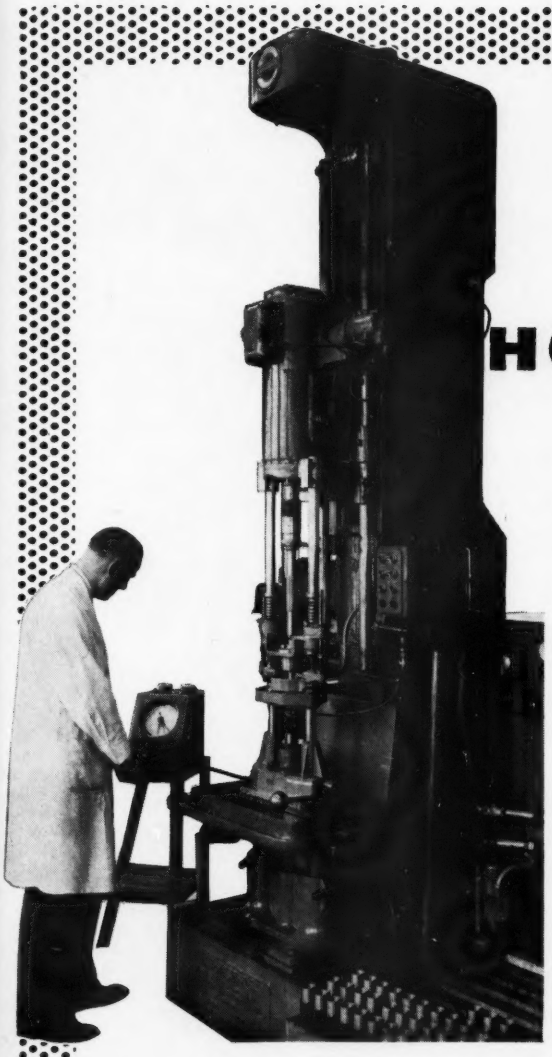

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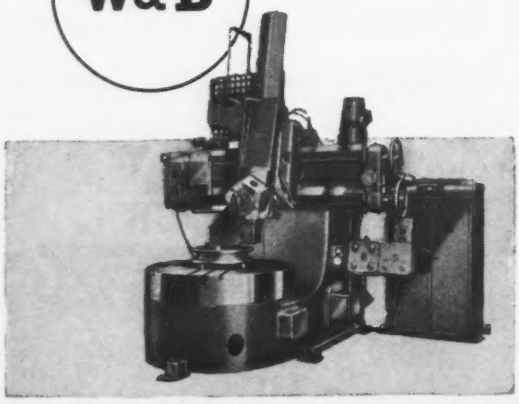

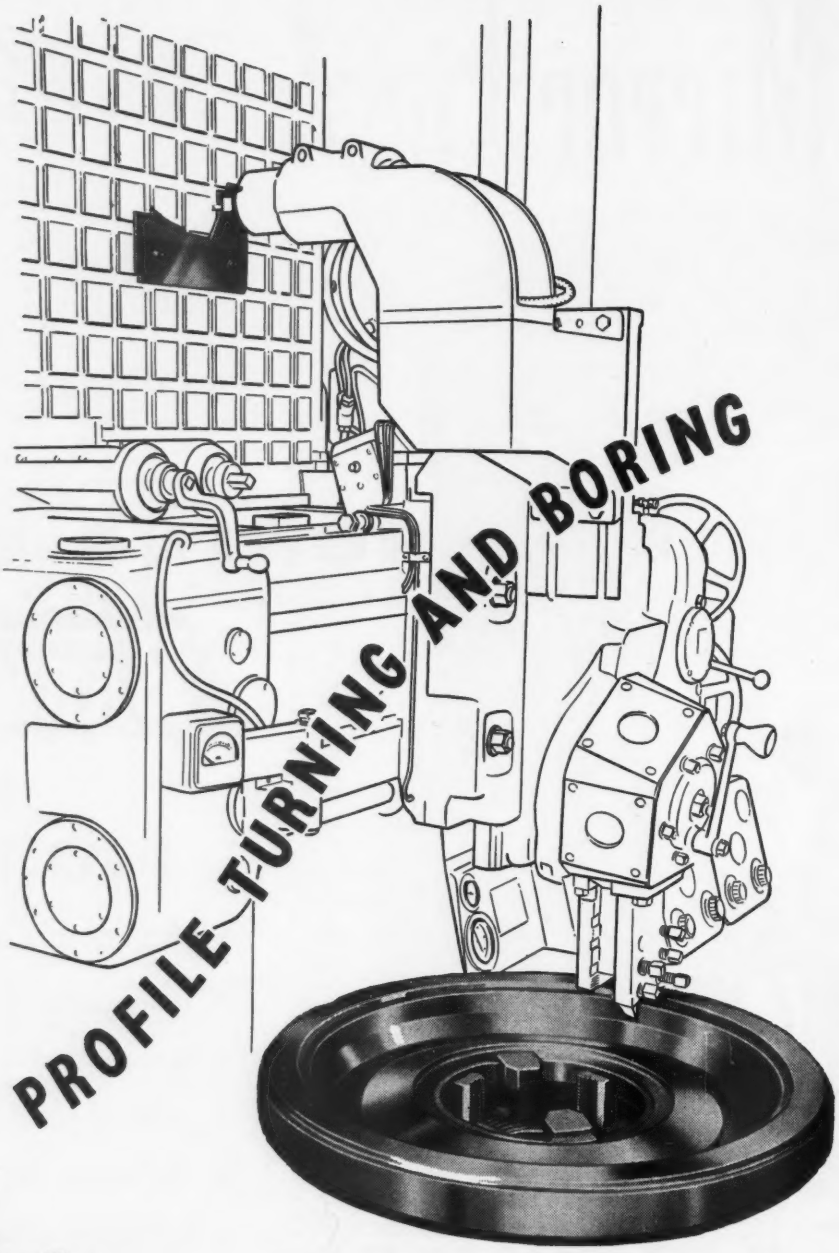

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The application of electronic profile turning and boring equipment to the Webster and Bennett range of vertical boring mills opens up a wide new field of uses for these versatile machines. Although specifically designed for copying applications, when not required the electronic control may be disengaged and the machine operated as a standard machine under mechanical control.

Machine capacities range from 36″ to 72″ chuck diameter, and machines can be supplied with or without the electronic profiling equipment.

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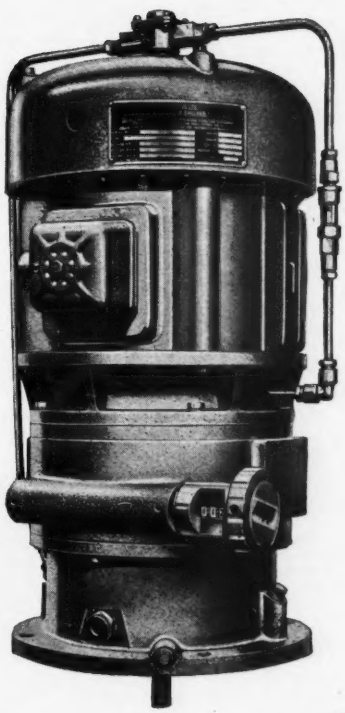
- Units can also be supplied with the output shaft uppermost.



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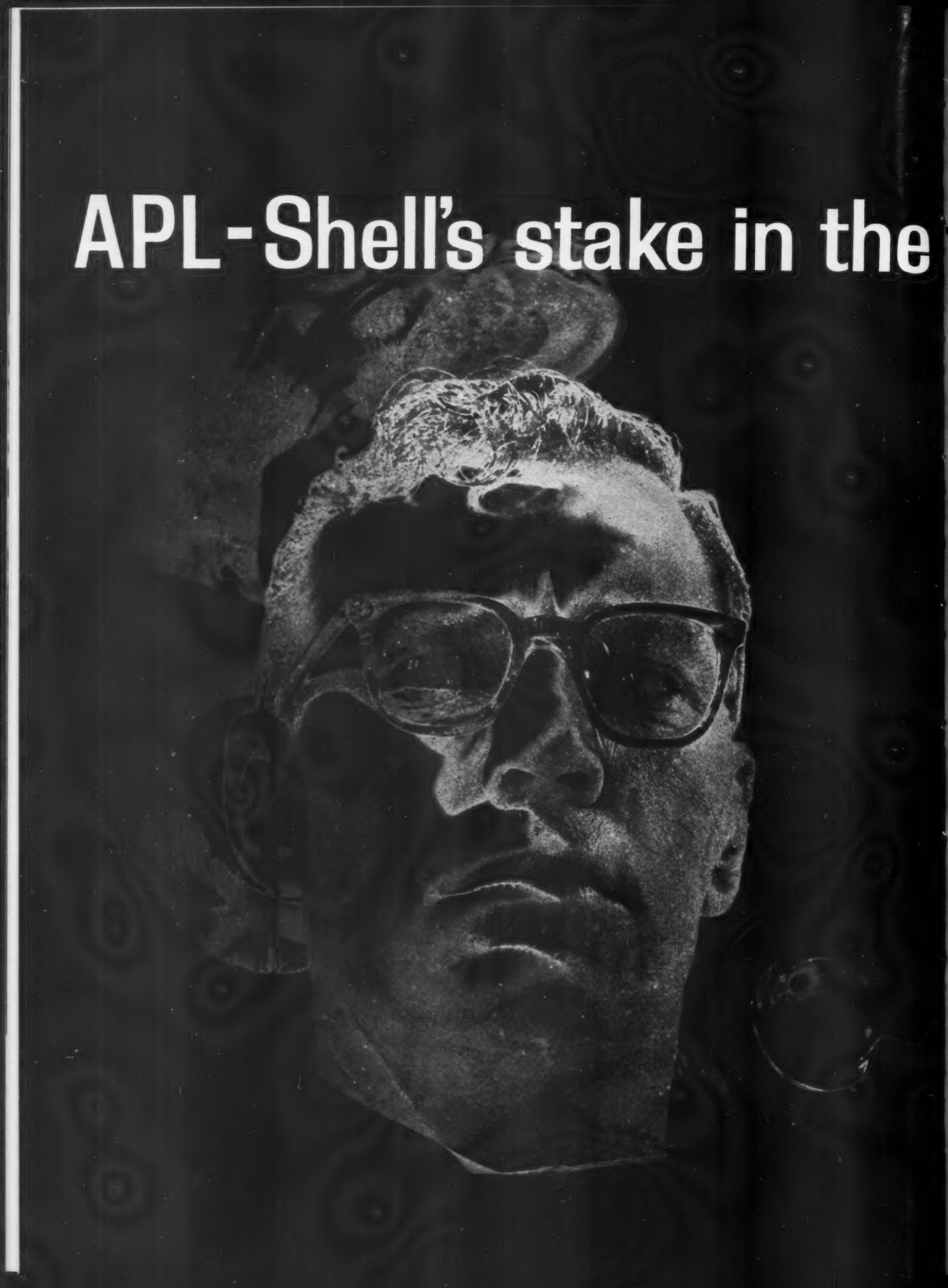
APL-Shell's stake in the fi



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e first nuclear decade

To a world hungry for energy, nuclear power brings rich promise. With it, inescapably, come complex new problems which can be mastered only by imaginative thinking.

Conventional lubricants, for instance, are useless when exposed to radiation. They break down, thicken and form harsh solids. Yet the lubricants needed for mechanisms close to the reactor may have to withstand radiation 4 million times stronger than would kill a man. Some of them have to take such punishment continuously for two years or more, for the complicated mechanisms they lubricate cannot be serviced without closing down the reactor altogether – a costly business with plant involving a capital outlay of some £50,000,000.

In 1953, when it was realised that radiation-resistant lubricants were essential, Shell decided to start an extended programme of research. Special groups were set up at Shell's Thornton Research Centre, a generous budget allocated, and their own Cobalt 60 source of radiation installed. Repeated tests took place there and under actual reactor radiation at the United Kingdom Atomic Energy Research Establishment at Harwell.

In 1957, after four years of work, the Shell group introduced the world's first range of Atomic Power Lubricants under the brand name of Shell APL – Shell's stake in the first nuclear decade.

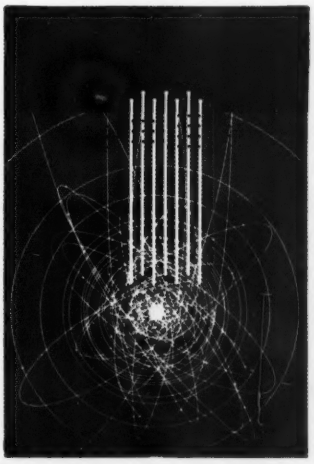
Today, Shell APL is still the only range of proved radiation-resistant lubricants on the market. Oils and greases from this range, as well as other Shell Industrial Lubricants, are in daily use at many nuclear establishments in the United Kingdom and elsewhere – in lubricating control-rod mechanisms, manipulators, electric motors, blower fans and steam turbines. They have also been chosen for the new British atomic power station under construction at Bradwell in Essex.

Here is Shell leadership in lubrication in action – anticipating a need, undertaking fundamental research, and finally developing the products to solve a problem of world-wide importance.

The Research Story

In the hundreds of complex hydrocarbons examined, very different reactions to radiation were observed according to the configuration of the atoms in the molecules. Highly complex structures of an entirely different nature from the original material were formed. Following extensive experiments, the Shell APL range of lubricants was developed and proved. Included are such oils as Shell APL 729, mainly for use in blowers. This oil now has a performance equal to a good quality modern turbine oil. Shell APL 700 series greases have been tested in bearings operated within the BEPO reactor and subjected to CO_2 gas under pressure at 150°C. After receiving a total dosage of 2.7×10^{18} thermal neutrons plus associated radiation, the grease and bearings were found to be still in good condition.

Other lines of research include the latest developments in the use of radio-active isotopes in the measurement of wear. Recent results have been published in a paper presented at the 1958 Geneva Conference.



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another proof of Shell leadership in lubrication

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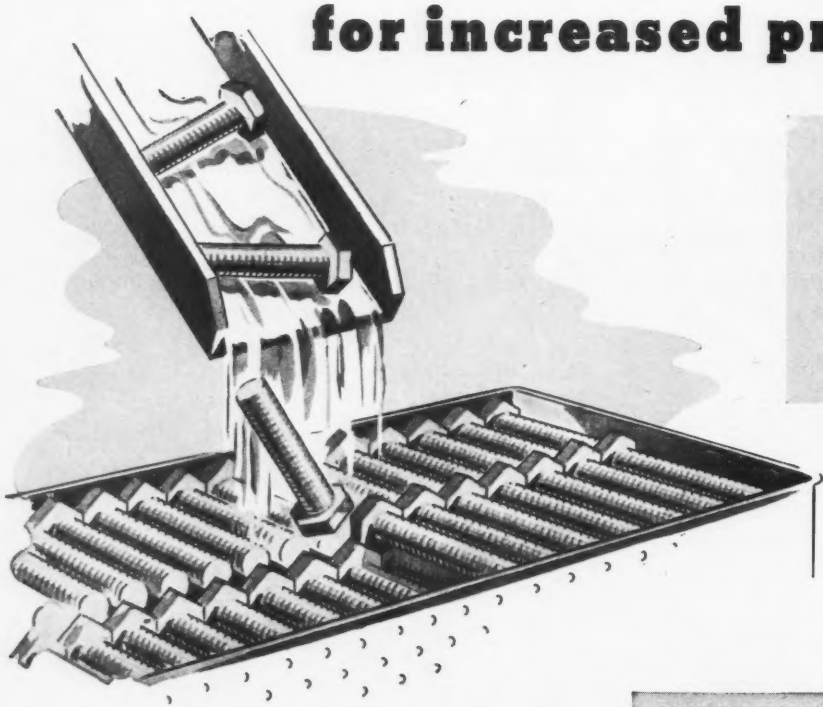

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MILLS LEDLOY bright steel bars contain a small percentage of lead, giving greatly improved machining properties to all standard qualities, Freecutting, Casehardening, Carbon, Heat-Treated Carbon and Alloy steels without impairing their physical properties in any way.
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PECIAL
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CVA NEWS

No. 240

NEW CONCEPT IN AUTO-TURRET DESI

CONSTANT THROW TURRET

NEW DEVELOPMENT ON CVA No. 8 AUTOMATIC

BRIGHTON, Tuesday

CVA today announced that their No. 8 ½-inch Automatic is now equipped with a new turret of patented design. Increased length capacity and smoother indexing are major features of the new design, a CVA spokesman revealed.

The Constant Throw Turret, now in full production, has undergone rigorous tests for more than two years. It is of simple but ingenious design, has fewer working parts and costs no more despite its extra features.

The new CVA No. 8 Automatic

NEW FEATURES

Crank throw of the turret is *constant* at all slide positions, even when indexing at the rearmost working position. Indexing clearance is thus greatly extended, allowing the full cam movement to be used for cutting operations.

Extensive screw adjustment of the turret, added to extra indexing clearance, permits production of components of far greater overall length.

Advantage can also be taken of the constant throw feature for machining successive lengths from the turret on longer-than-normal work.

SHOCK-FREE INDEXING

Secret of the indexing mechanism is its harmonic action—the cam lever roller hugs the cam throughout the indexing movement. This eliminates the need for a rear cushion and buffer, eliminates also those twin bogies of conventional indexing — turret drag and bounce.

NEW SKIP INDEXING UNIT SPEEDS DEEP DRILLING

Greatly improved performance on deep drilling operations is offered by the new CVA No. 8 Skip Indexing Attachment, also announced today.

Used on the constant throw turret, the new attachment provides single or multiple withdrawals of the drill, permitting holes to be drilled more rapidly and to greater depth than previously possible.

The attachment is operated by a disc cam and trip mechanism which withdraws and returns the turret in a fraction of a second. Normal single or double indexing is not restricted.

CVA No. 8 machines of current design can be fitted with skip indexing either at the factory or in the field.

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Here is wide enc diverse t either hig carbide t 18 fast sp speeds (in selected, slow ratios

15.5 : 1. This only provides speeds but alw cutting rates fo less of the mat used; it also carbide tools f tions while thr ventional high-s

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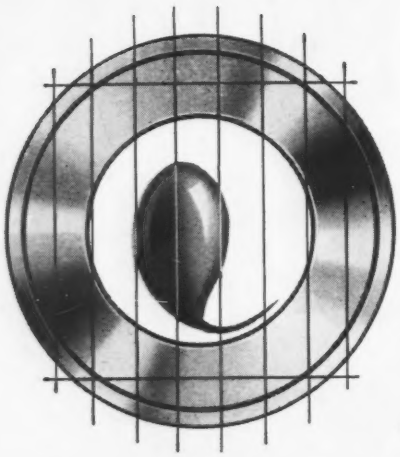
TECHNICAL LITERATURE

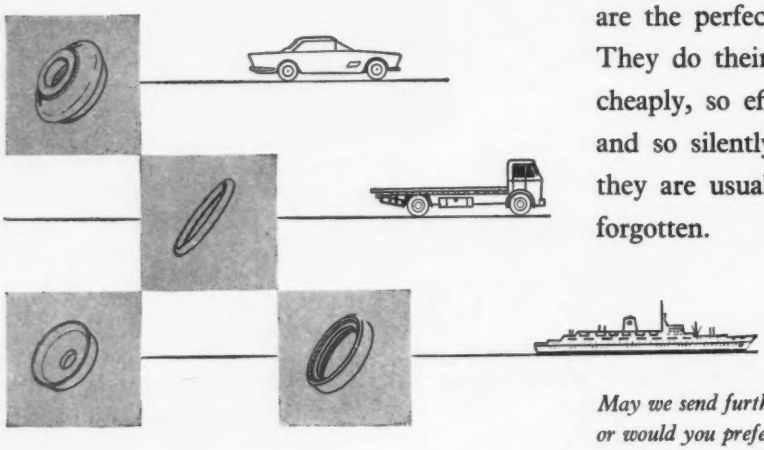
New literature illus



oil

is a difficult prisoner...

and it must be kept in solitary confinement too; no fraternisation with that insidious enemy dirt, either. SuPerfect Oil Seals are the perfect gaolers. They do their job so cheaply, so efficiently, and so silently that they are usually completely forgotten.



May we send further details, or would you prefer to see our technical representative?

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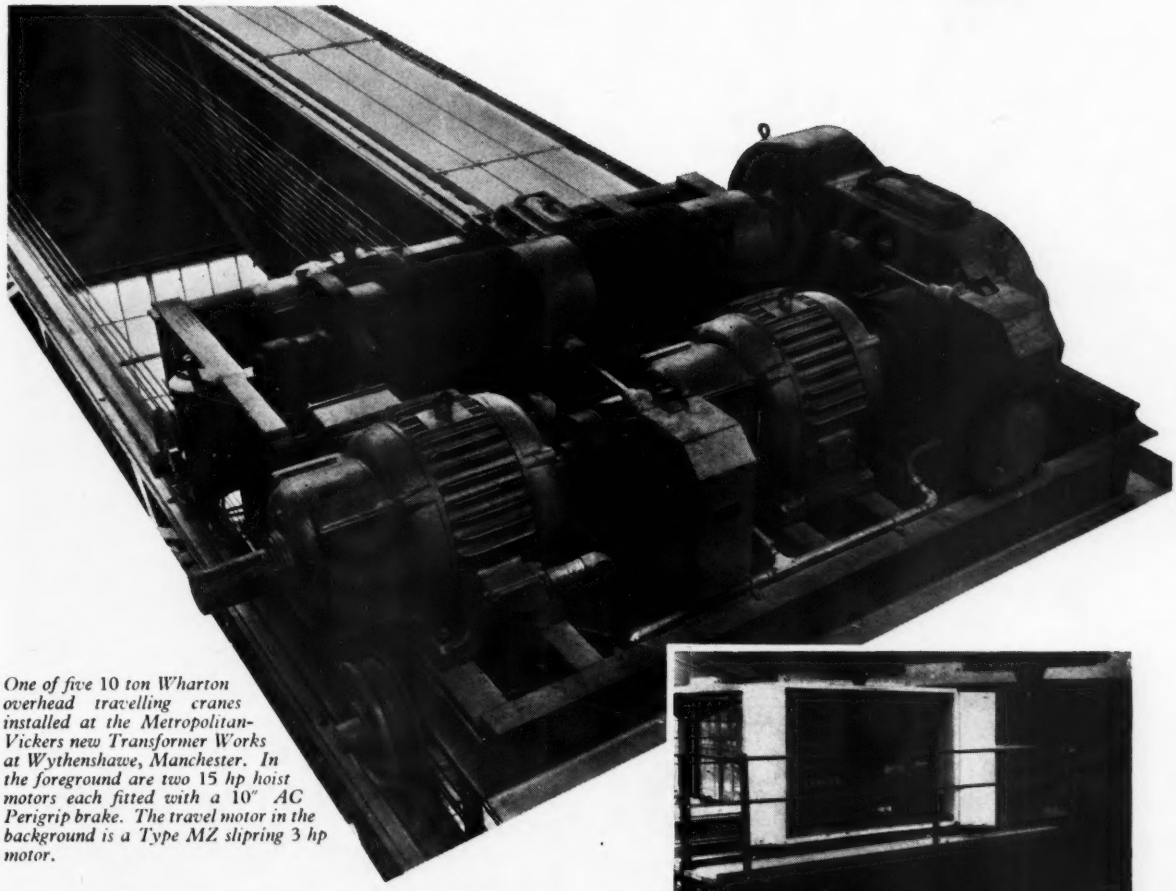
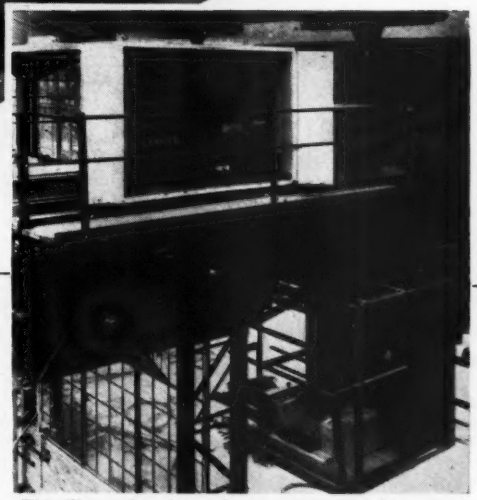
Complete Hoist Control without Mechanical Braking



One of five 10 ton Wharton overhead travelling cranes installed at the Metropolitan-Vickers new Transformer Works at Wythenshawe, Manchester. In the foreground are two 15 hp hoist motors each fitted with a 10" AC Perigrip brake. The travel motor in the background is a Type MZ slipring 3 hp motor.



This illustration shows the contactor control gear and the operator's cabin.

The new Metrovick system of AC Crane Hoist Control employs two identical slipring induction motors, permanently geared to the hoist motion and running at the same speed. These motors running in conjunction give :—

- Creep speeds hoist and lower, varying little with load.
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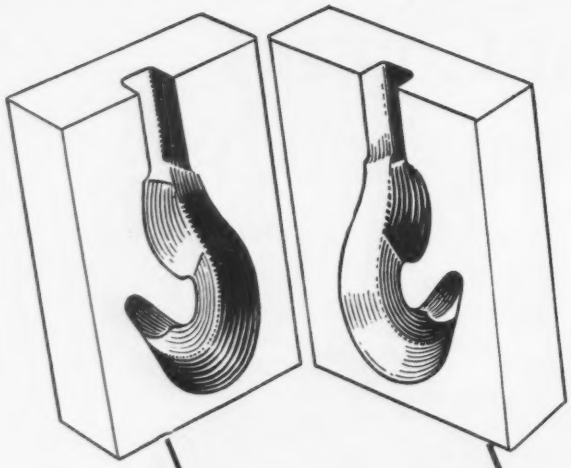
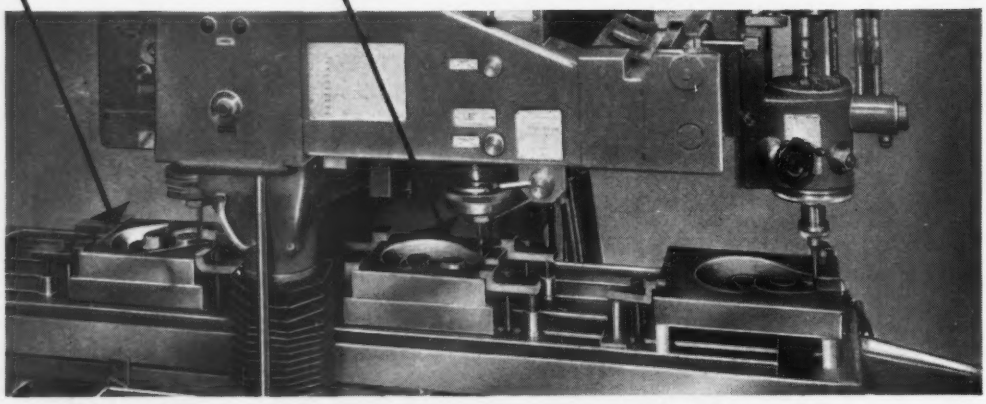


Both halves at once



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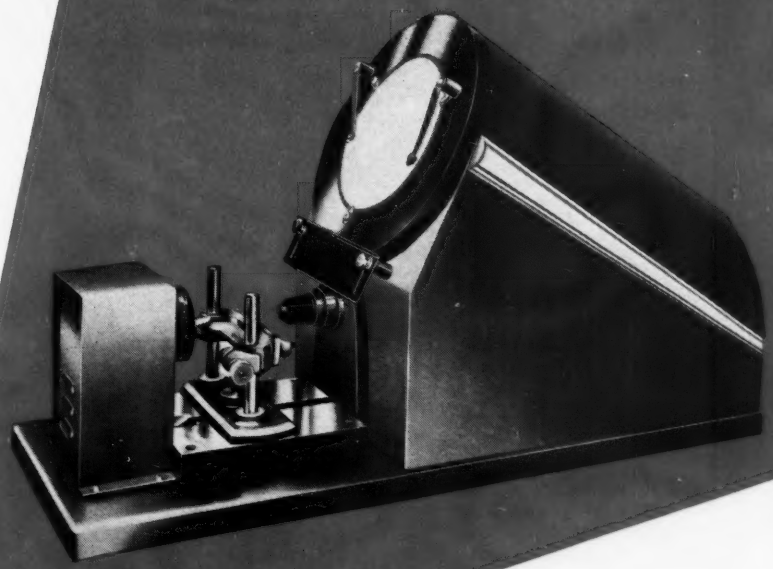

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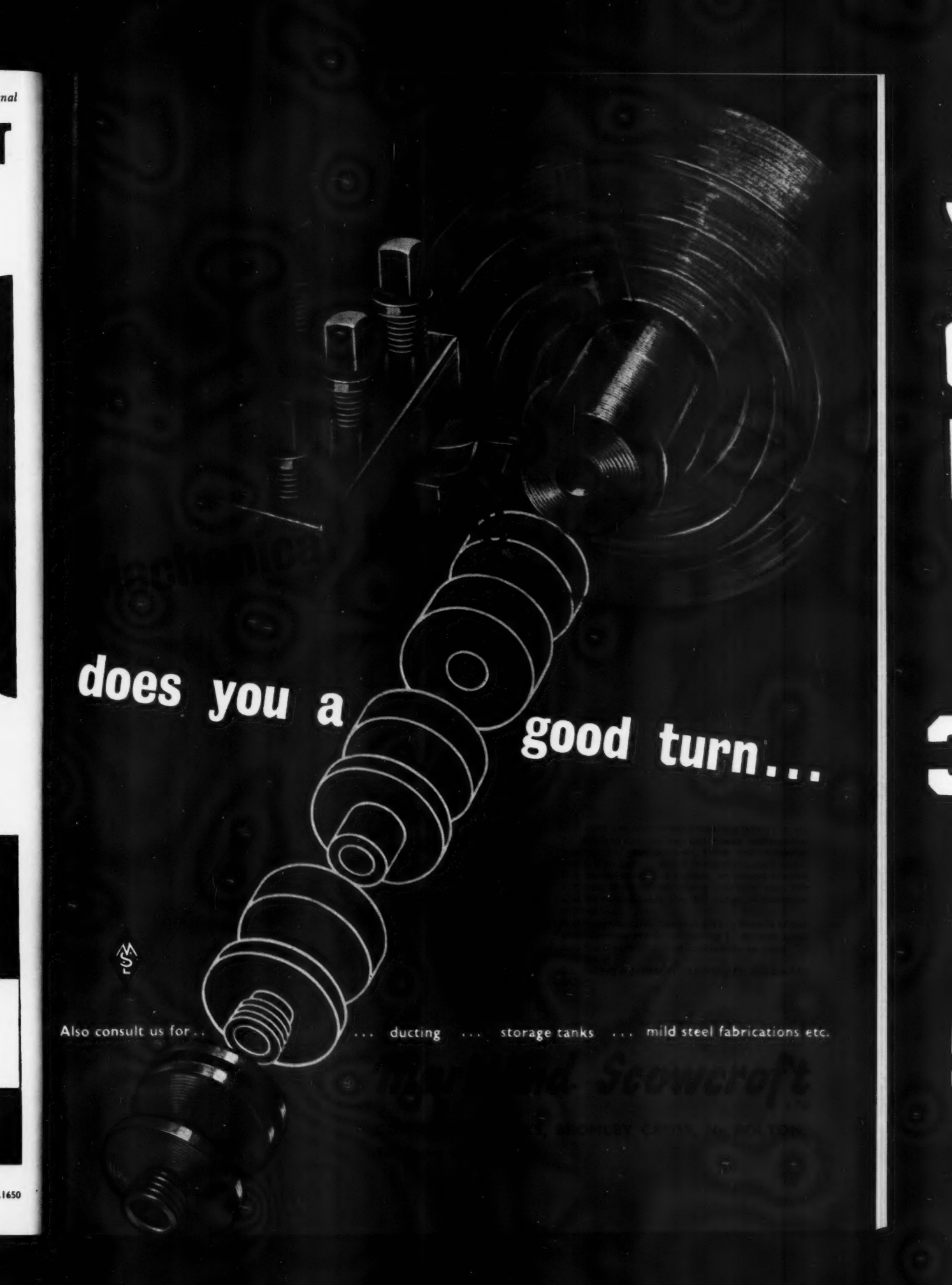
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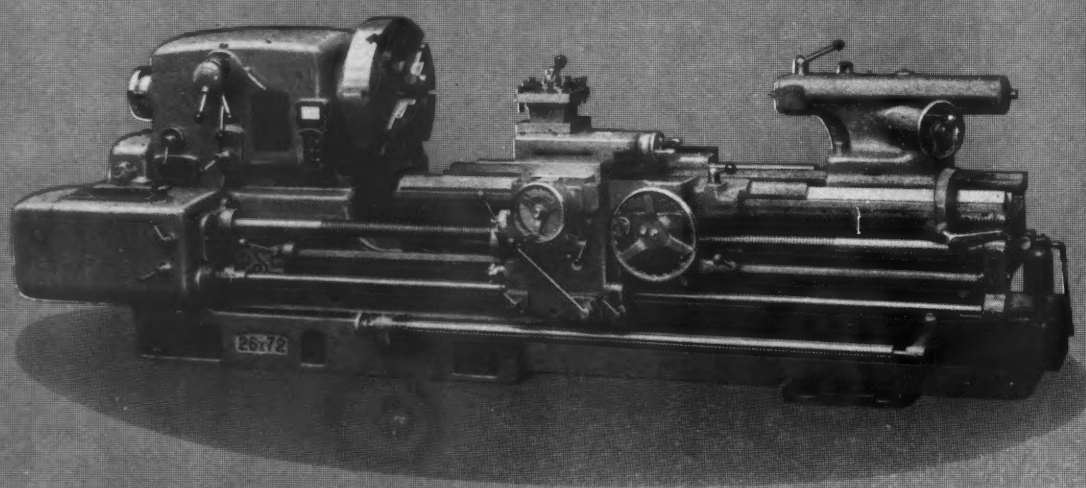

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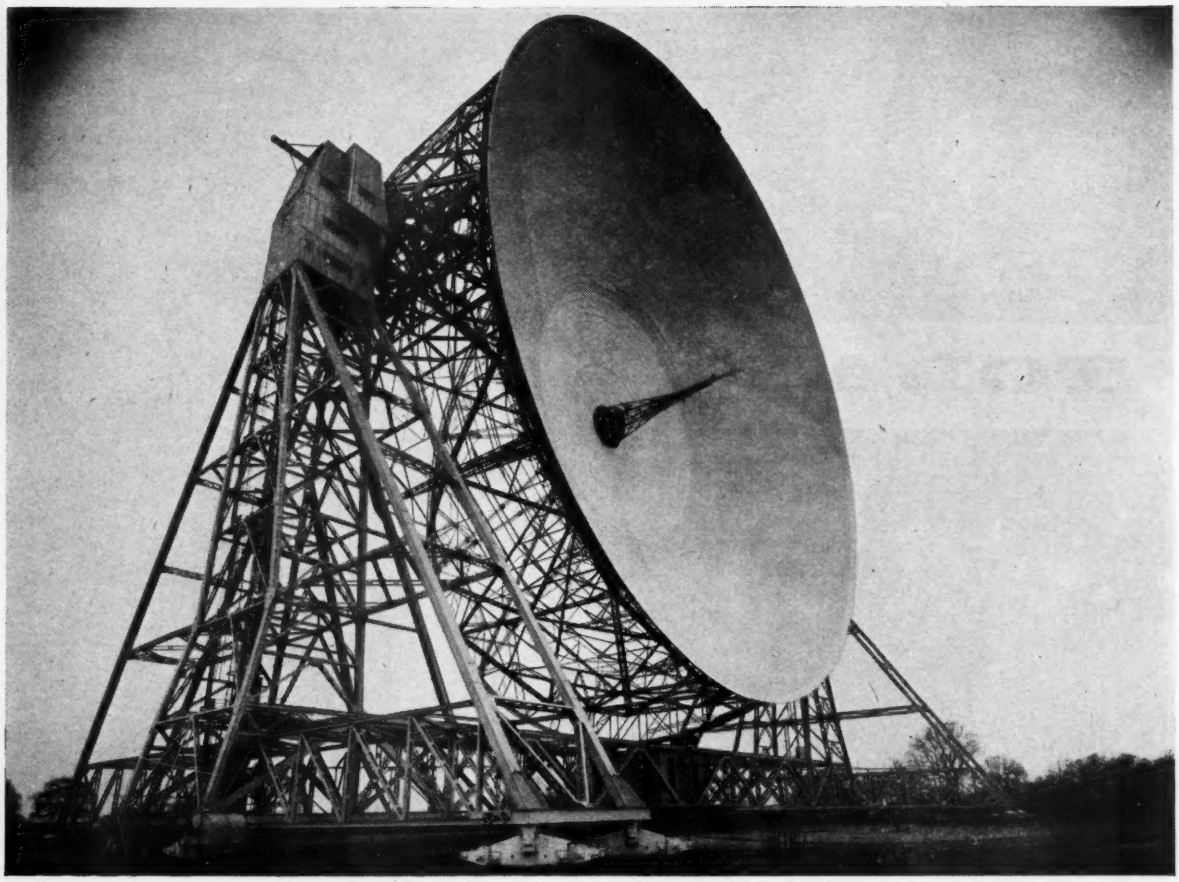

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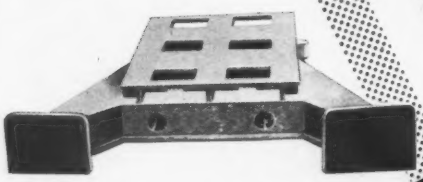

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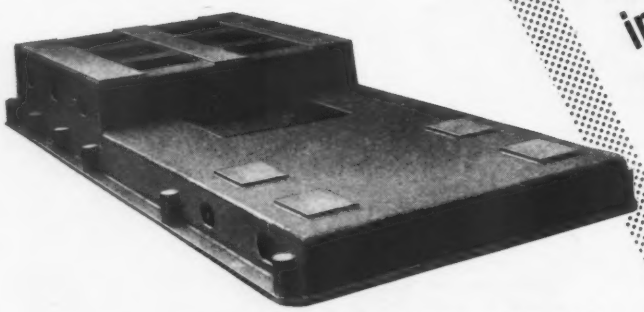

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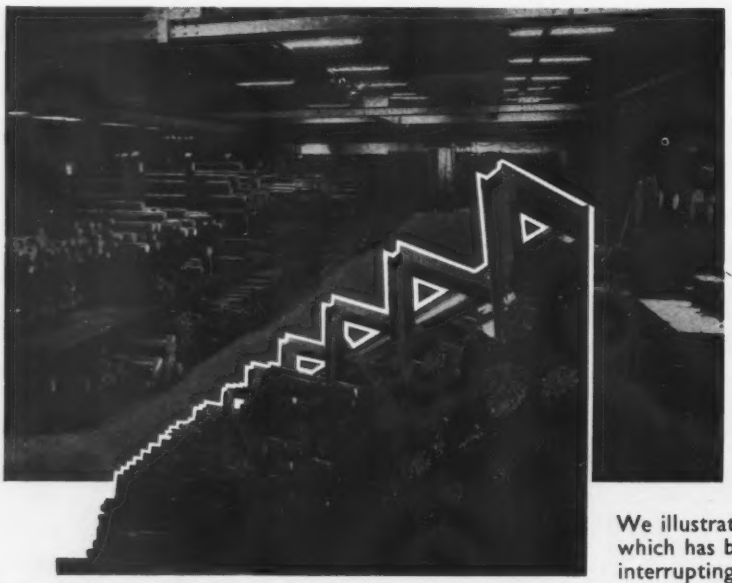

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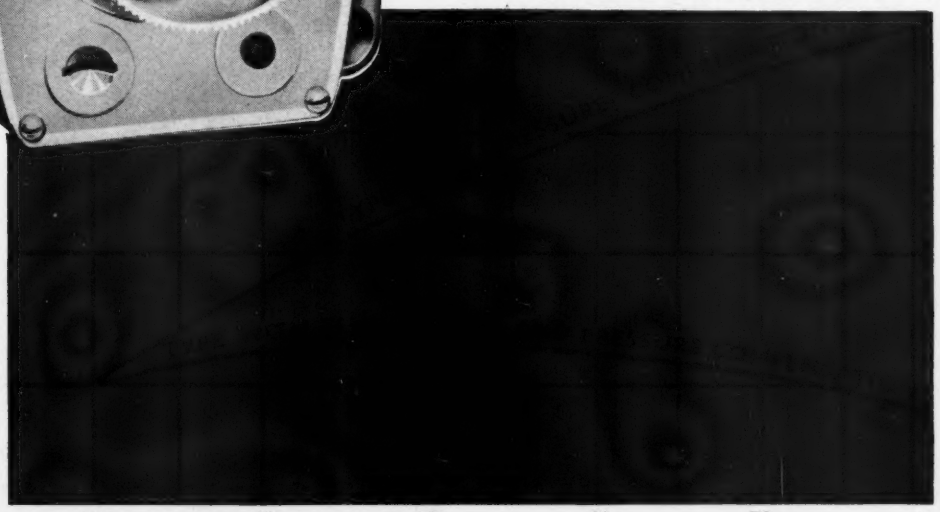

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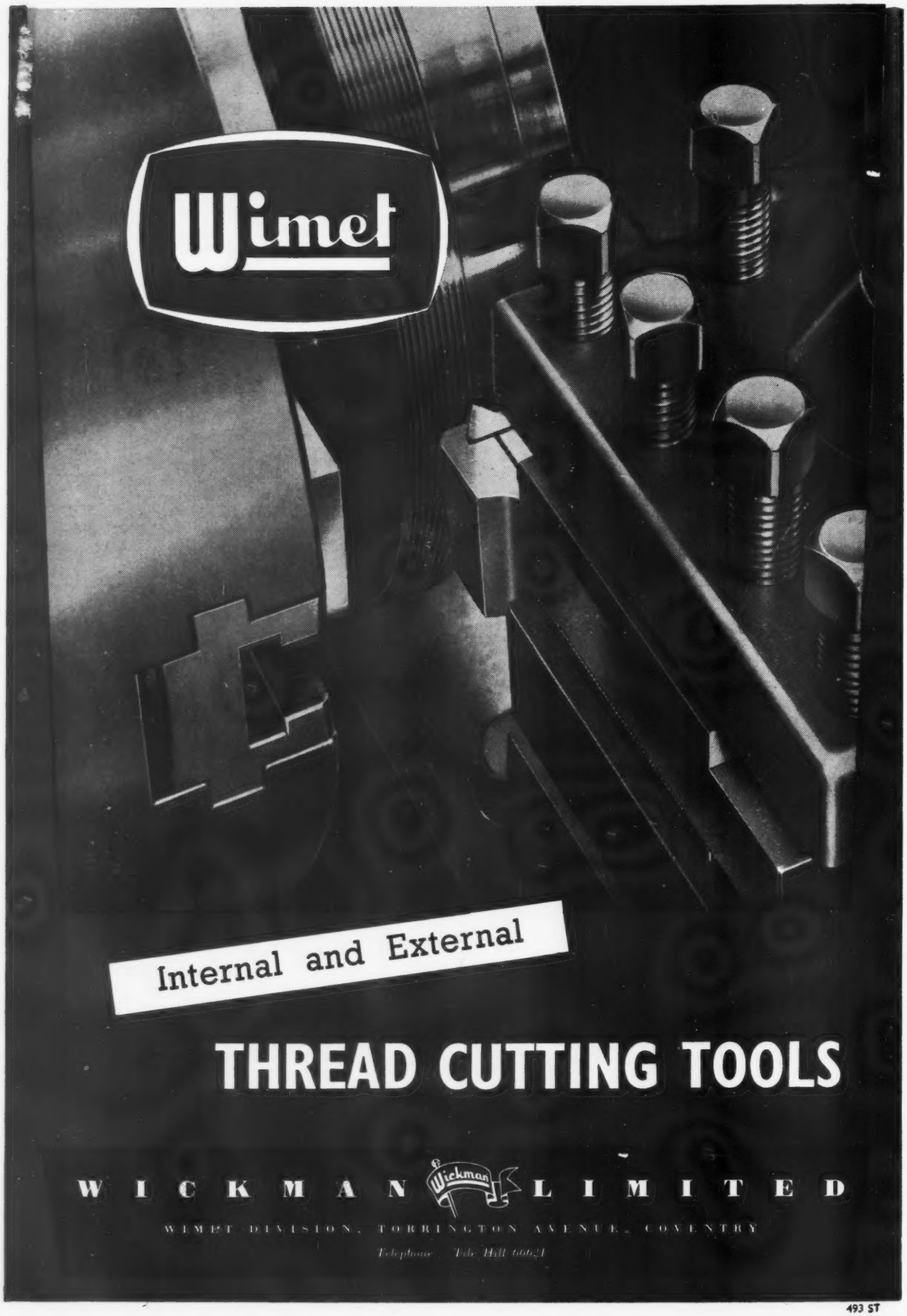
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The Institution of Production Engineers Journal
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The Production, Fabrication, Properties and Uses of Some of the Newer Metals

by Dr. N. P. INGLIS

Research Director,
Metals Division,
Imperial Chemical Industries Ltd.

Presented to the Institution of Production Engineers on 11th March, 1959, at the University of Birmingham, as THE 1958 VISCOUNT NUFFIELD PAPER

IT is perhaps important to commence by emphasising that within the compass of a single lecture the comprehensiveness of the title cannot be matched by similar comprehensiveness of the matter in the lecture itself. This is, I think, an excusable fault, often found in most named lectures of this sort where the lecturer usually takes as his subject a broad survey of a particular field and perforce must sacrifice depth for broadness.

Briefly, the object of the present lecture is to emphasise the growing industrial importance of a number of metals which a few years ago were little more than laboratory curiosities and certainly not of industrial significance. It is proposed to illustrate this thesis mainly by dealing fairly fully with titanium, zirconium and beryllium, with some more brief reference to other of the newer or less usual metals, such as niobium, hafnium, tantalum, etc.

For a great many years use of metals for structural purposes has mainly involved iron, aluminium, copper, nickel, zinc and lead. It is true that alloy additions of other elements to these metals have been

made and considerable success achieved in such alloying, but broadly speaking the above six have been the main engineering structural basic metals until very recent times.

The metals referred to above—titanium, zirconium, beryllium, niobium, etc. — are none of them new in the sense that their existence has only recently become known. Thus, the existence of titanium was recognised in 1791 and it was isolated, admittedly in impure form, in 1825. The existence of zirconium was recognised at about the same time and it was isolated in 1824. The existence of beryllium was recognised in 1798 and first isolated in 1828. The existence of niobium was recognised by various chemists over the period 1801 - 1844. It might, therefore, be asked why these metals, which have been lying dormant, so to speak, for so many years should now be of interest to practical engineers.

The reason, of course, is that new inventions, new designs, and new processes are calling for entirely new materials of construction. Thus, the discovery and development of nuclear energy, which can rightly be regarded as leading to a second Industrial Revolution, is playing a major part in stimulating effort in some of these new metals. Just as the development of the use of steam in railways and shipping rather more than 100 years ago necessitated a material of construction superior to cast and wrought iron and, therefore, fathered the manufacture of steel in gross tonnages, so the special requirements of nuclear engineering demand the availability of materials having certain special requirements. Then again, high speed flight and the initiation of what the newspapers are fond of calling "The Space Age" brings the need for materials having special properties, in particular, metals of low density and high strength with the added ability of being able to withstand higher temperatures than the earlier light metals such as aluminium and magnesium. Thirdly, the power-producing and chemical and petroleum industries demand materials of construction having higher strength at elevated temperature than the metals previously available and also materials resistant to such corrosive conditions as cannot be met by even the special corrosion-resistant steels, the discovery and development of which in the second and third decades of this century was one of the landmarks in metallurgical history. And so the reason for our very real and active interest in such metals as titanium, zirconium, beryllium, niobium and others, is simply that the advances of mechanical and physical science and practice demand it.

These metals are no longer solely of academic or subsidiary interest; they are now, or will shortly be, an essential part of the overall industrial picture and be available choices for the engineer when selecting the material of construction to suit the requirements of his mechanism, structure, or the like.

Before we say a few words separately about each of these metals it might be worthwhile to look at the availability of different metals in the earth's surface, and Table I is, therefore, presented with this object.

This Table shows the well-known fact that aluminium, iron and magnesium, in that order, are the most abundant of our metals, but perhaps it is less appreciated that titanium is by no means rare and that metals like zirconium and vanadium are actually more abundant than the much more commonly used metals like nickel, copper and zinc.

titanium

extraction

Although, as mentioned above, titanium was isolated in 1825, it was not until exactly 100 years later than van Arkel and de Boer, by the very elegant method of thermal dissociation of the tetraiodide, produced the metal in a form sufficiently pure to allow a true assessment of its properties. It was then shown that in addition to a low specific gravity (4.5) the metal had very great corrosion resistance and could be readily alloyed to give material of tensile strength equal to or greater than high tensile steels. This combination of properties is of great and immediate interest to the aircraft and aero engine designer, and in the years following 1925 work was done on the selection and development of an industrial scale process for the manufacture of titanium.

The natural form of titanium is rutile (TiO_2) or ilmenite ($(FeTi)O_3$), but, on account of the extremely great affinity of titanium for oxygen and the profound effects on the properties which even a small amount of residual oxygen has, no satisfactory direct method of reducing the oxide to the metal has been found. An indirect route was therefore necessary whereby the oxide is first converted to the tetrachloride — a normal and well established process — and the tetrachloride is then reduced, either by magnesium or sodium, at a temperature of 800°C - 900°C in a sealed vessel under an argon atmosphere.

The process was placed on an industrial basis by Kroll, the greatest name in titanium technology, who used the magnesium route. The products of his reduction reaction are a rather coke-like mass of

TABLE I
OCCURRENCE OF VARIOUS METALS IN THE EARTH'S SURFACE

	Parts per million or grammes per ton
Iron	50,000
Aluminium	81,300
Magnesium	20,900
Nickel	80
Copper	70
Zinc	132
Lead	16
Titanium	4,400
Zirconium	220
Beryllium	6
Niobium	24
Hafnium	4.5
Vanadium	150
Tantalum	2.1
Tin	40

titanium metal sponge and magnesium chloride. The removal of the magnesium chloride by leaching with acid caused difficulties and it is generally preferable to purify the Kroll reaction product of the magnesium reduction process by vacuum distillation.

The process developed by I.C.I. in this country differs appreciably from the Kroll magnesium process in that sodium is used as the reducing agent. It is believed that this has several advantages over the magnesium route, since the reaction mass is very much easier to grind and the sodium chloride by-product is readily removed by leaching. The fact that the titanium metal produced by the sodium process is in finely divided or granular form is advantageous when it comes to the subsequent compacting to make consumable electrodes for melting, and also has advantages in adding other elements in order to make the required alloys.

Both processes produce equally pure titanium metal, but it is considered that the sodium process is cheaper in capital and running costs and it is thought to be capable of greater development. Most of the plants built in the United States operate on the magnesium route, although the most recent plant there uses the sodium route. In Great Britain the only large plant is that built by I.C.I. and this, with a nominal annual capacity of 1,500 tons, operates on the sodium route. It might be mentioned here that production capacity for titanium metal in the United States is estimated at 25,000 - 30,000 tons per annum.

On the subject of purity it should be noted that the most likely impurities in raw titanium are oxygen and nitrogen, which cause considerable increase of hardness with corresponding increase in strength and loss of ductility and malleability. The effect of these impurities on hardness is such that a measurement of hardness is accepted as a yardstick or rough indication of the purity of the raw material. The hardness of the purest titanium yet reported was found to be 50 D.P.N., whereas commercially pure titanium as normally produced in Great Britain today is 120 - 130 D.P.N. (this is equivalent to 110 - 120 on the standard Brinell scale, which in turn is equivalent to 100 - 110 on the sub-standard Brinell test favoured by some U.S. producers).

melting

Titanium is so reactive when molten that it attacks all the refractory oxides normally available for furnace linings and crucibles and, in addition, it must be melted out of contact with air. Consequently, the methods employed for melting titanium and the production of ingots differ very considerably from those employed with the older metals.

A metal crucible, very thoroughly water-cooled, is used with an internal source of heat and the crucible must be sealed in such a way that melting can be carried out in a vacuum or in an atmosphere of argon. These necessary requirements have been translated into practice by arc melting a consumable electrode in a water-cooled copper crucible maintained under vacuum. A schematic representation of this melting system is shown in Fig. 1. The consumable electrode is made by mixing the raw titanium granules with the desired alloying elements and compressing the mixture into pieces strong enough to be handled, pressures of

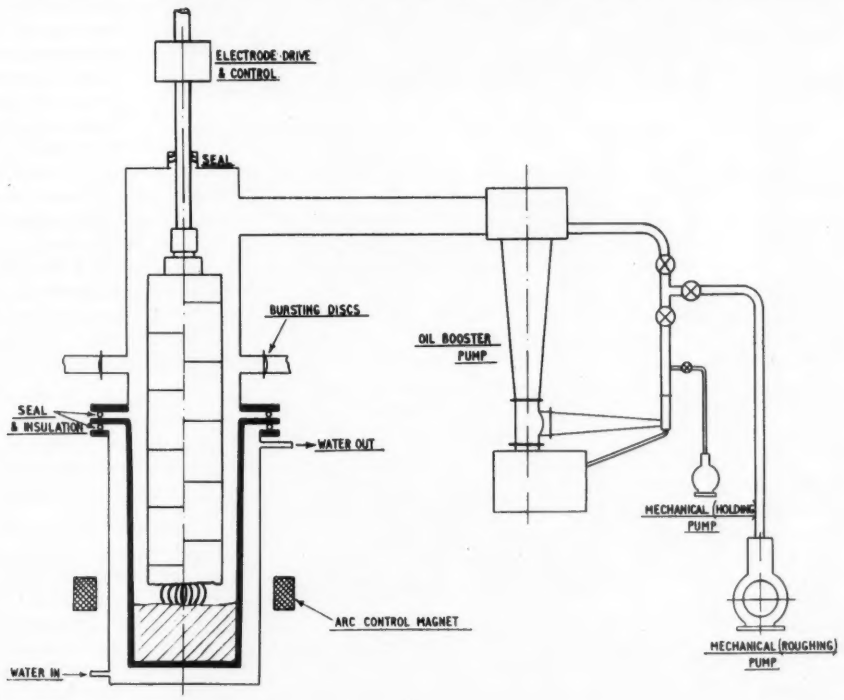

Fig. 1.
Schematic representation of consumable electrode arc melting furnace

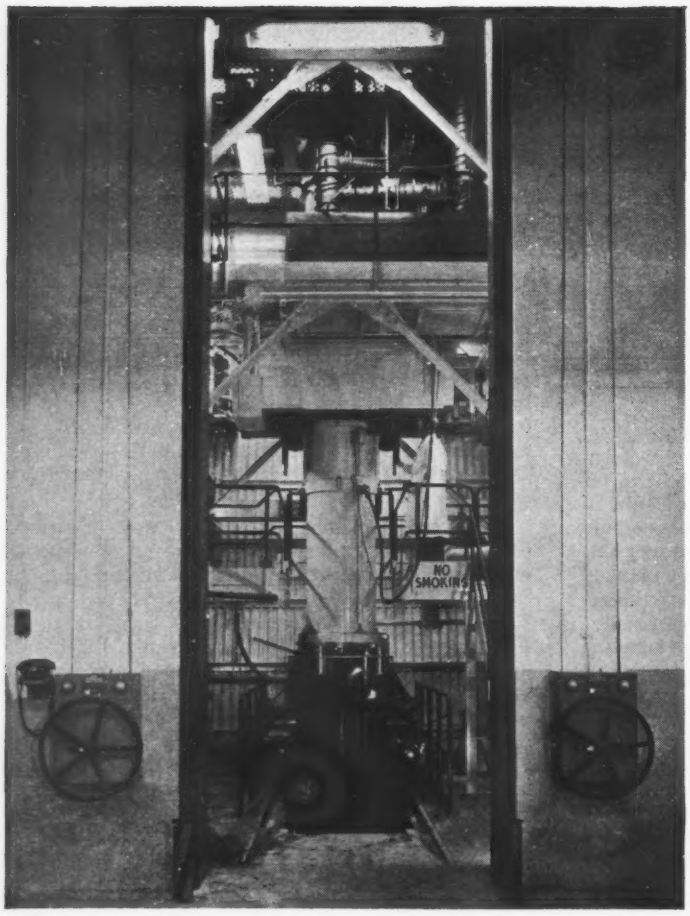

Fig. 2.
Production scale consumable electrode arc furnace used for the melting of titanium and zirconium

10 - 20 tons per sq. in. being required. These pieces are then welded together to give the required weight to be melted. As mentioned earlier, it has been found in practice that the granular raw titanium produced by the sodium reduction method is very much more easily compacted than the coarser product of the Kroll process and also allows the better incorporation of the alloying elements, with less risk of segregation in the subsequent ingot. Fig. 2 is a photograph of a production scale consumable electrode arc furnace which is believed to be the largest of its kind in Europe, and is capable of producing a 4,000 lb. titanium ingot.

The danger of puncturing the crucible wall and so causing contact between water and molten titanium must be considered and, therefore, the furnace is isolated during melting behind blast walls and is operated entirely by remote control, as shown in Fig. 3.

wrought forms

Whilst the conversion of titanium ingots into plate, rod, sheet, and other wrought forms required has not been without difficulty, most of the major problems involved have now been overcome and, in general, conversion to these forms has been carried out with equipment used for similar processes on other metals.

The difficulties experienced in hot working have been more chemical than mechanical, in the sense that they have been concerned with the prevention of undue contamination by oxygen, nitrogen and hydrogen, all of which have detrimental effects on the metal. At one time it was thought that it might be necessary to sheath the metal for hot working in order to prevent atmospheric contamination, but fortunately it was found that the diffusion of oxygen and nitrogen in titanium at hot working temperatures was relatively slow, and by very carefully observed heating times and procedures these impurities could be confined in the hot worked product to a thin surface layer which *must* be removed by chemical and mechanical methods.

Hydrogen, on the other hand, diffuses very readily, and although it can be removed by subsequent heating *in vacuo* the more usual course is to limit the chances of hydrogen contamination by extremely strict control of the furnace atmosphere.

Hot extrusion is an extremely convenient way of producing metal in various sectional forms, but unfortunately it has not proved as successful for titanium as for many other metals. This is because of the well-known feature of titanium that when forced through a die it is prone to seize and so cause imperfections in the extruded metal surface. A considerable amount of attention has been given to this problem, the

solution to which clearly depends upon more effective high temperature lubrication. Some success has been achieved by sheathing the workpiece in copper and also by the use of glass as a lubricant, and although there is still room for further improvement satisfactory progress is being made.

Whilst the cold rolling of commercially pure titanium is straightforward and calls for no comment, the cold rolling of the high tensile titanium alloys is only possible by repeated small reductions and frequent intermediate annealing. This difficulty is not peculiar to titanium; it is encountered in the cold rolling of any metal with a tensile strength as high as 60 - 70 tons per sq. in. and a high ratio of proof stress to ultimate stress. So far it has been the general practice with such alloys to hot roll in single sheets, or, where thicknesses of, say, 22 s.w.g. are required, to pack roll a number of sheets together, sometimes within steel cover plates. Hot rolling methods such as these perforce give somewhat poorer surface finish and dimensional tolerances than if finishing were done by cold rolling, and it is not surprising, therefore, that a considerable research effort is in progress to overcome these difficulties. One obvious approach lies in developing a heat treatable alloy which in one condition of heat treatment is soft enough to be readily cold rolled, but which can then be strengthened by heat treatment after rolling. Important and promising results have already been obtained in this connection.

The cold drawing of titanium and titanium alloys is hampered by the tendency referred to previously for the titanium to seize in the die, but various methods of reducing this tendency have been developed. Thus, quite fine titanium wire has been successfully drawn by silver plating the stock, or by various chemical treatments such as treating with cyanide or phosphate or controlled oxidation at high temperature. All these methods solve the problem by providing a surface which will hold a lubricant and which really prevents direct contact between the metal and the die.

Because of the sensitivity of titanium when hot to atmospheric gases, fusion welding of the metal is really only possible by the arc processes carried out in an inert atmosphere as, for example, the well-known tungsten argon-arc process. Even here precautions have to be taken additional to those used with the argon-arc welding of the older metals. Thus, it is necessary to protect those hot surfaces which are not normally protected by argon issuing from the welding torch. Several ingenious ways of doing this have been devised as, for example, the use of special backing plates with channels to supply argon to the underfaces of the weld. In some cases fusion welding by this process has been carried out in a chamber filled with inert gas. Titanium can be resistance, pressure and flash-butt welded satisfactorily without difficulty and particularly good welds have been obtained, not only in titanium, but in some of its alloys by the well-known flash-butt welding method.

Provided suitable precautions are taken, very satisfactory welds can be made by the argon-arc process in commercially pure titanium, the welded material giving a very satisfactory bend radius and also having a tensile strength equal to that of the unwelded material. This is also true to some extent of the alpha alloys, but it is not true of the alpha-beta alloys. Even where atmospheric contamination has been completely prevented, welded joints in such alloys are lacking in ductility owing to reactions which occur during cooling. The ductility of such material can be improved to some extent by heat treatment after welding but, generally speaking, welded joints in the

Fig. 3.
Remote control panel of a commercial titanium melting furnace

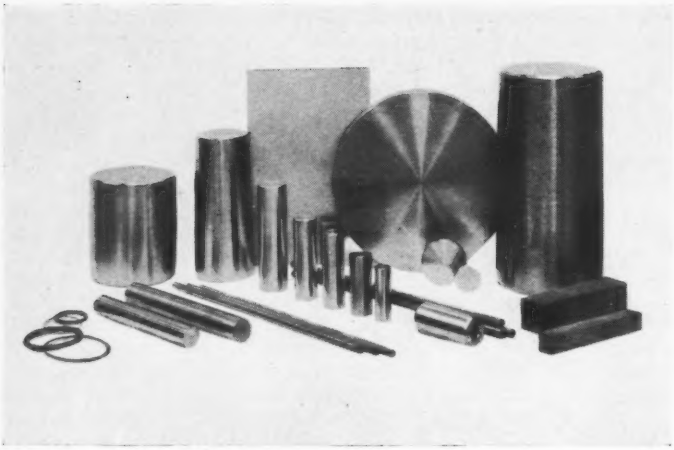

Fig. 4 (left). **Some wrought forms in titanium**

Fig. 5 (below). **Examples of forged, welded, machined and manipulated titanium**

alpha-beta alloys must be given a lower rating or weld efficiency factor.

That the various forming and fabricating processes, to which brief reference has been made, have proved satisfactory in practice and have reached full commercial status is demonstrated by Figs. 4 and 5, which illustrate groups of miscellaneous wrought, welded, machined and manipulated forms.

properties

A very great deal of investigation of the physical and mechanical properties of titanium and its alloys has been done and it is not possible to do justice to this volume of work in a brief statement such as this. The softest grade of commercially pure titanium now being regularly produced will, after melting and processing to wrought form, have a tensile strength of the order of 25 tons per sq. in. with excellent ductility and formability. This very soft and ductile material is of main interest to the chemical engineer for whom the extreme corrosion resistance of titanium, combined with ease of welding and manipulation into various shapes, is particularly attractive.

Those concerned with aircraft and aero engine design are more interested in the higher strength alloys and Table II gives the room temperature mechanical properties for a number of the titanium alloys in commercial production or in an advanced stage of development today.

Up to 882°C titanium has a hexagonal structure and in this form is known as alpha-titanium; above this temperature it changes to a body-centred cubic form, known as beta-titanium. The addition of other elements raises or lowers this change point and by appropriate alloying and heat treatment it is possible to obtain alloys that consist entirely of the alpha phase, entirely of the beta phase, or a mixture of the two. Each of these types has characteristic properties. Thus, the all-alpha alloys are strong and maintain their strength well at higher temperatures, but are difficult to fabricate, particularly into sheet; the all-beta alloys are normally less strong, are easier to work, but are usually unstable if used at elevated temperatures. In addition, they have much lower resistance to creep at elevated temperatures than the alpha alloys. The alpha-beta alloys are intermediate in type and give the best combination of high strength and ductility.

Because of the relatively high melting point of titanium (1660°), it was at one time thought that the metal would have particularly high strength at elevated temperatures. This has not been found to be so since the fall in strength of titanium with rise of temperature is appreciable, e.g., the strength at

TABLE II

TYPICAL ROOM TEMPERATURE MECHANICAL PROPERTIES OF COMMERCIAL TITANIUM ALLOYS IN THE ANNEALED CONDITION

Nominal Alloy Content	Designation	Form	0.1% Proof Stress t/in²	U.T.S. t/in²	% El. on $4\sqrt{A}$ (bar) or 2 in. (sheet)	% RA
5% Aluminium 2.5% Tin	Titanium 317 Hylite 30 A–110 AT Ti–5Al–2.5Sn RS–110C	Bar Sheet	51 48	57 51	16 17	32
1.5% Aluminium 1.5% Manganese	Titanium 314C Hylite 20	Bar	35	46	25	49
1.5% Aluminium 3.0% Manganese	RS–110	Sheet	52	57	17	
2.25% Aluminium 3.25% Manganese	RS–110B	Sheet	55	60	18	
4% Aluminium 4% Manganese	Titanium 314A Hylite 40 C–130 AM RS–130 MSM–4Al–4Mn	Bar	63	68	17	35
6% Aluminium 4% Vanadium	Titanium 318A Hylite 45 C–210 AV Ti–6Al–4V RS–120A MSM–6Al–4V	Bar Sheet	62 60	68 64	11 14	31
5% Aluminium 2.75% Chromium 1.25% Iron	RS–140	Bar	66	71	17	40
5% Aluminium 1.5% Iron 1.4% Chromium 1.2% Molybdenum	Ti–155A	Bar	63	71	16	35
2.2% Iron 2.1% Chromium 2.0% Molybdenum	Ti–140A	Bar	57	62	20	35
3.0% Aluminium 5.0% Chromium	MSM–3Al–5Cr	Bar	63	69	13	35
8.0% Manganese	C–110M RS–110A MSM–8Mn	Sheet	60	65	15	

400°C of commercially pure titanium is rather less than 40% of the strength at room temperature. Considerable improvement in this respect can be obtained by alloying and a comparison of the strengths at high temperature of a number of different alloys is shown in Fig. 6. It will be seen that this Figure gives the stresses required to cause a given amount of plastic strain in a given period, this or a similar criterion being required usually by designers of high temperature equipment, who are not only concerned that their selected material should not actually fracture under the selected stress, but also should not give more than a certain allowable deformation. This Figure shows very clearly the considerable improvements in high strength brought about by suitable alloying, and further improvements in this direction can be confidently expected, since, although a considerable amount of work has been done in the titanium alloy field, there are many areas still relatively unexplored.

corrosion resistance

Whilst the major interest in the metal in its early days was in the aeronautical field, and indeed still is, the extremely good corrosion resistance has naturally attracted the attention of chemical plant

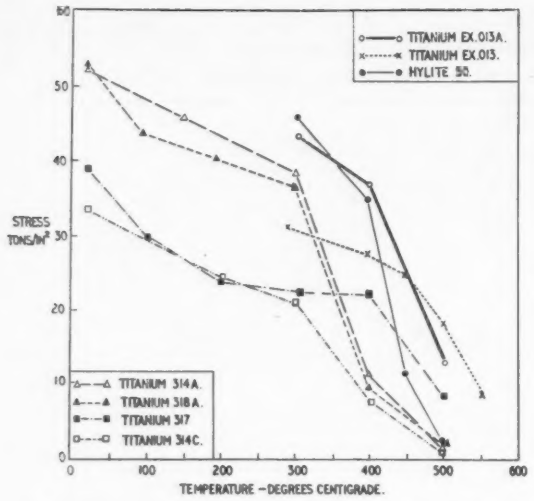

Fig. 6. Stress to give 0.1% total plastic strain in 300 hours for various titanium alloys

designers. Titanium, in fact, is resistant to a wider range of corrodents than are the chromium-nickel austenitic steels.

It would be both tedious and too encroaching on limited time and space to attempt any list of the corrodents to which titanium is resistant, but to give a general indication of its class in this respect the following statistics may be of value. Recently, when examining a table of corrosion data covering the action of 220 different corrosive media, the writer noted that in 172 cases titanium was in class A of the classification used by the U.S. Electro-Chemical Society, i.e., attack was less than 0.005 in. per year. In 25 other cases it was in their class B, i.e., attack between 0.005 in. and 0.05 in. per year, which, depending on various circumstances, is often regarded as tolerable. In 23 cases only out of 220 was the rate of attack such as to make titanium unsuitable for use. These are very remarkable figures and clearly put titanium in what might be termed without exaggeration the super corrosion-resistant class.

Perhaps time might be taken to say just a little about its really remarkable resistance to sea water, which is so ubiquitous a corrodent. A very great many tests have been done in this medium and the results confirmed by many investigators. In the ordinary sea water immersion tests, even when the sea water is heavily polluted, there is virtually no attack at all on titanium, even after very long periods of immersion; impingement tests in aerated sea water when carried out for many thousands of hours have failed to cause the slightest pitting; it is almost completely unattacked under "deposit" or differential aeration conditions which heavily pit corrosion resistant steel; perhaps most remarkable of all, its fatigue limit in sea water is found to be actually slightly greater than its fatigue limit in air.

Its use as a material of construction in chemical plant is only just commencing, but there is little doubt that in spite of its high price this application will grow.

Naturally, efforts are being made to reduce the cost of plant made in titanium by developing methods of lining, and Fig. 7 shows a large vessel, constructed in mild steel but lined throughout, branches included, with commercially pure titanium.

Whilst it will be seen that the corrosion resistance of plain, untreated titanium is very great indeed in a large variety of media, the story of corrosion resistance does not end there. A new chapter has been opened by the discovery of the remarkable way in which the corrosion of titanium can be minimised or prevented even under conditions which would normally cause attack on the metal. Titanium is not a noble metal and, as with the high chromium steels and aluminium, the corrosion resistance is due to the presence of a strong, tenacious film of oxide which heals rapidly when damaged. Growth of this protective film can be stimulated if the electrode potential of the metal is raised by connecting it to a positive source of direct current. Aluminium and stainless steel can be similarly treated and, indeed, the well-known process of anodising aluminium is simply an example of thus stimulating growth of the protective oxide film. With metals such as stainless steel and aluminium, the conditions under which the protective film can be increased are limited to a few electrolytes and a very restricted range of potentials. With titanium, however, it has been found that the growth of the protective

Fig. 7. Titanium-lined vessel for chemical plant

TABLE III
EFFECT OF IMPRESSED CURRENT ON CORROSION RATE OF TITANIUM

CORRODING MEDIUM CONCENTRATION BY WEIGHT	TEMPERATURE (°C)	CORROSION RATE IN IN./YR. WITH APPLIED ANODIC VOLTAGE OF 1·5	FACTOR BY WHICH RATE OF CORROSION IS REDUCED
40% H_2SO_4	60	0·0000028	33,000
40% H_2SO_4	101	0·0075	1,980
35% H_3PO_4	60	0·000156	400
35% HCl	60	0·005	670
50% formic acid (N_2 stirred)	101	0·0031	80
25% oxalic acid	100·5	0·0095	330

TABLE IV
THERMAL NEUTRON ABSORPTION CROSS-SECTIONS OF DIFFERENT METALS

THERMAL NEUTRON ABSORPTION CROSS SECTIONS . (in Barns)	
Material	**Cross Section**
IRIDIUM	430
RHODIUM	150
HAFNIUM	105
GOLD	98
SILVER	62
TANTALUM	21
PLATINUM	8·1
PALLADIUM	8·0
CHROMIUM	7·9
TITANIUM	5·6
VANADIUM	5·1
NICKEL	4·6
COPPER	3·69
IRON	2·53
MOLYBDENUM	2·5
NIOBIUM	1·1
ALUMINIUM	0·23
ZIRCONIUM	0·18
LEAD	0·17
MAGNESIUM	0·063
BISMUTH	0·032
BERYLLIUM	0·010
CARBON	0·003

film can be stimulated and any damage immediately made good in a very wide range of media and over a very wide range of potentials.

Reference to Table III shows the amazing reduction in attack on titanium when subject to this electro-chemical mechanism. All the corrodents listed in Table III attack plain, unprotected titanium but if a very small positive direct current voltage is applied and maintained between the titanium and a cathode, the corrosive attack is reduced by a factor which in some cases runs into thousands.

Another method of anodically protecting titanium is to connect it to a more noble element, such as platinum. This can conveniently be done by depositing on the titanium a very thin film of platinum, and it should be emphasised that this film need not be continuous and can, in fact, be subject to gross porosity, since the film is in no sense intended to be a protective barrier because at any discontinuities the subsequent electro-chemical action causes the formation or healing of the protective film on the titanium.

This latter development of platinised titanium is expected to have a very big future in electrolytic processes, where the problem is so often to find an anode which will conduct electric current into a corrosive electrolyte without causing catastrophic corrosion of the anode material.

zirconium and beryllium

Before dealing individually with zirconium and beryllium it will be helpful to say something of the requirements of certain materials of construction in nuclear engineering, because the principal uses of both zirconium and beryllium are in this field.

The nuclear power reactors now under construction and several of those still in the exploratory and development stages, are of the type in which the heat of the nuclear reaction is abstracted by a coolant which is circulated past the reacting fuel. Now the nuclear fuels such as uranium, plutonium and thorium, are severely attacked by all the coolants likely to be used, such as carbon dioxide, water, or liquid metals. In addition, direct contact between the fuel and the coolant would result in radioactive contamination of the coolant, which is later processed in relatively normal equipment to transform the extracted heat into usable energy. Consequently it is necessary to protect the fuel by a sheath or can and the material of this can must have certain properties; this limits choice quite appreciably. Briefly, the properties required are as follows:

1. The chosen material must be compatible with both fuel and coolant, i.e., it must not alloy with the fuel and it must be resistant to corrosion by the coolant, in both cases over the whole temperature range involved.

2. To achieve good neutron economy it must have low capacity for the absorption of neutrons, or expressed in nuclear engineering terms, it must have a low neutron absorption cross section. Table IV shows the neutron absorption cross sections for a wide selection of metals.

3. It must have reasonable strength at operating temperature so as to resist without fracture distortion of the fuel and also should have reasonable ductility to accommodate any swelling of the fuel.

4. It should preferably have good thermal conductivity and also be capable of being processed into the shapes required which are not, ideally, simple shapes since finning and the like of the cans can greatly improve heat transfer (see, for example, Fig. 8, which is typical of the sort of shape of the magnesium alloy cans presently used in the CO_2 gas cooled reactor stations).

The importance of zirconium and beryllium from the point of view of the second requirement above will be very clear from Table IV which also shows that, unless one can afford to be extremely prodigal in neutrons, choice is restricted to relatively few metals at the lower end of the Table and some of which would obviously not fulfil other requirements. With regard to zirconium and beryllium, details of the manner in which they fill these other requirements will emerge later in this lecture, but it can be said that zirconium admirably fulfills the requirements of compatibility with water as the coolant, but would not be so satisfactory if CO_2 were the coolant. Beryllium, on the other hand, would not be satisfactory with water as the coolant, but it has excellent resistance to CO_2, both wet and dry, up to a temperature between 500°C - 600°C, and above 600°C if the gas is dry.

Fig. 8. Longitudinally finned cans in a magnesium alloy of the type used in current gas-cooled reactors

Details of the strength, ductility, etc., of these two metals will be given later but it can be said that they are adequate to meet reasonable design requirements. The ability to shape them into the forms required is still being studied, but they can certainly be fabricated into most of the commoner wrought forms, although the designer may have to be content with a somewhat simpler final shape than that which would be possible with many other metals.

It will be seen, therefore, that although a principal use for both beryllium and zirconium is for cans and other items of what is colloquially termed "reactor ironmongery", they are not at present competitive with each other, since the selection of one as compared with the other depends on the type of reactor.

The British nuclear power programme is based on the gas-cooled reactor using unenriched, or only slightly enriched, uranium as the fuel. In such a reactor neutron economy is particularly important. In the first British commercial scale nuclear power reactors, a magnesium alloy will be used as the canning material. It will be seen from Table IV that whilst magnesium has a relatively low neutron absorption cross section it is still about six times greater than that of beryllium. Perhaps even more important is that the strength of the magnesium alloy at moderately elevated temperatures is not particularly good and, therefore, the surface temperature of a magnesium alloy can must be limited to about 400°C - 450°C. In order to increase the thermodynamic efficiency by increasing this temperature, a change must be made from this magnesium alloy and clearly, from what has been said already, beryllium would be a natural selection.

zirconium

extraction

The extraction, fabrication and general metallurgy of zirconium are so similar to those of titanium that much of what has already been said about the latter is true for zirconium and perhaps the simplest way would be to point out the main differences in the processing of the two metals.

In the first place it is important to note that as all zirconium minerals contain between 0.5% and 2% of hafnium, and as the presence of hafnium is extremely detrimental to the value of zirconium for nuclear purposes — as will be clear from Table IV — one problem in the extraction is the removal of hafnium. Moreover, this removal must be very complete, since the usual specification for zirconium of reactor quality is that the hafnium content must not exceed 100 parts per million.

Several methods for achieving this separation have been devised, such as fractional distillation of the double fluorides, solvent extraction and ion exchange techniques, but all one can do within the compass of this lecture is to emphasise the extreme importance of this separation, since zirconium is almost entirely required for nuclear energy purposes.

The reduction of the metal is, as with titanium, by reduction of the tetrachloride and the magnesium reduction route has invariably been followed. The differences from the titanium reduction process arise from the fact that zirconium tetrachloride is a solid, whereas titanium tetrachloride is a liquid and, also, zirconium chloride is soluble in magnesium chloride so that the salts cannot be tapped from the reaction crucible as can be done in the titanium reduction process. Purification of the reaction mass is, therefore, by vacuum heat treatment, in which magnesium chloride is removed partially by melting and partially by distillation and the magnesium metal is distilled and collected on condensers. A sodium reduction process, as for titanium, has not been worked out for zirconium. World production capacity for zirconium metal is probably of the order of 3,000 tons per annum, chiefly in the United States.

melting and fabrication

When it comes to melting, the equipment and techniques suitable for titanium and previously described have been and are being used with complete success for zirconium, always bearing in mind that the melting point of zirconium is 1850°C as compared with 1650°C for titanium. The hot working of zirconium is generally similar to that of titanium but does introduce some additional difficulties. Thus, oxygen and nitrogen diffuse more rapidly in zirconium than in titanium and, therefore, the depth of the hardened layer for material heated at the same hot working temperature and for the same time as for titanium will probably be 50% greater. This naturally means that one uses as low a temperature as possible for hot working and controls the time at temperature even more rigidly than is the case with titanium. For the same reason there is a greater incentive in the case of zirconium to anneal or otherwise heat treat in argon or under vacuum. Descaling is difficult enough with titanium, but it is even more difficult with zirconium, and mechanical means are usually employed. Furthermore, although surface contamination by diffusion of gases must be avoided as much as possible with titanium, the tolerance to such contamination is even less for zirconium. Hot-worked and heat-treated zirconium must be very thoroughly pickled in order to remove any residual surface gaseous contamination, because the subsequent corrosion rate in service is adversely affected by any nitrogen contamination. Such pickling involves the use of very strong pickling agents of the hydrofluoric-nitric acid type.

Apart from these differences the whole production process must be geared to an even higher standard of purity than the high standard employed with titanium. In particular it is necessary to control to minimum levels nitrogen, aluminium and titanium because of adverse effects on corrosion, most other elements because of their effect on neutron capture, and certain elements which have a long half-life after irradiation, e.g., cobalt. Naturally, these precautions apply to welding, where very similar methods are used as for titanium, but again with special emphasis on minimising all contamination due to gaseous diffusion and particularly nitrogen. With suitable precautions open air argon-arc welding has proved satisfactory but enclosed welding may be necessary in some cases. Incidentally, the unusually high standards of purity which apply have clearly thrown a very heavy burden on the analytical chemists involved in this class of work. Not only have they had to work out the general analytical chemistry of zirconium, but they have had to apply their techniques and methods to the determination of quantities far below those normally required in the general metallurgical industry.

That these standards can be, and indeed are being maintained, is perhaps demonstrated by Fig. 9, which shows some fabricated articles in zirconium required for nuclear power stations.

alloying : effect on properties

Since the main virtue of zirconium is its combination of low neutron absorption capacity and corrosion resistance to water, a great deal of attention has been given to the effect of alloying in order to improve corrosion resistance without impairing neutron absorption characteristics. Under the conditions of high pressure and high temperature involved in a pressurised water cooled reactor, some corrosion of

★ ★

Dr. Inglis was born in 1902 and educated at the Liverpool Collegiate School and the Universities of Liverpool and Illinois.

He joined Synthetic Ammonia Nitrates, Ltd. (now the Billingham Division of Imperial Chemical Industries, Ltd.) in 1927 as a metallurgist, and in that capacity carried out research and development of metals suitable for what were then novel chemical processes. These included work on the influence on steels of hydrogen at elevated pressures and temperatures, and also on problems connected with the use of corrosion resistant steels.

Dr. Inglis was appointed a Director of the Metals Division of I.C.I. in 1947, and took up his present position as its Research Director, in 1951.

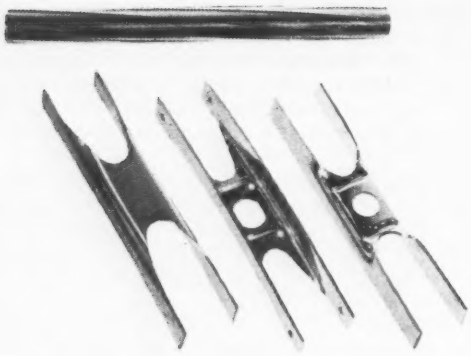

Fig. 9. Fabricated articles in zirconium

zirconium takes place in the form of a uniform attack on the metal with the formation of an oxide film. After a certain length of time there is a danger of what is known as break-away corrosion, which simply means that the film of oxide becomes discontinuous and flakes away from the surface (this state of affairs applies to metals other than zirconium). Thus, when commercially pure zirconium is exposed to very high temperature water (say 400°C) a glossy, black adherent film is formed, but it has been found that after a length of time, which varies from specimen to specimen, breakaway corrosion occurs and the film spalls off and corrosion increases at an accelerated rate. This has been attributed to impurities, particularly nitrogen, but also carbon, aluminium and titanium, although the content of these was very low as judged by the standards normally applied to metals. A very considerable alloy programme is therefore in progress, mainly, but not entirely, in the United States, in order to produce if possible an alloy which will give greater reproducibility in corrosion conditions, will increase the time before breakaway occurs and, if possible, reduce the corrosion rate in any post-breakaway period.

From the considerable amount of work which has already been done it seems clear that only a relatively few elements are likely to be helpful as alloying additions for improving water resistance and these are tin, iron, nickel and chromium. The first tangible result of this work has been the development of a zirconium alloy with 1.5% tin, 0.1% iron, 0.05% nickel and 0.1% chromium, which is generally known as Zircaloy 2. The tin content actually increases the initial corrosion rate, but it has the very important effect of producing an extremely adherent oxide scale and it certainly counteracts to a considerable degree the harmful effect of nitrogen. Whilst the nitrogen in this alloy must still be kept low the allowable nitrogen level is higher than that for unalloyed zirconium. It is considered that with this alloy a nitrogen content of 100 parts per million maximum can be tolerated. Even so, insufficient work has yet been done to be quite certain that if it is used with a nitrogen content below that mentioned, the corrosion resistance will be completely satisfactory and not unduly influenced by other factors, which may vary from ingot to ingot. Therefore, at the present time it is usual for production ingots to be passed forward for further processing on the basis of a corrosion test in pressurised water. Since such tests involve pressures of the order of 1,500 lb. per sq. in. and temperatures of the order of 400°C, elaborate apparatus is required such as that shown in Fig. 10, where the research worker is seen inserting into an autoclave a rack carrying the specimens to be tested.

It has already been mentioned that zirconium has relatively poor resistance to CO_2 at elevated temperatures, so that despite a fairly attractive neutron absorption character the metal is not a candidate as a canning material for the gas-cooled reactor. Even so it is not without use for the latter. For support brackets and components other than cans which require fairly good strength and reasonably good neutron absorption property, zirconium is a very reasonable choice. For such purposes it can be made somewhat more massive than the cans themselves, which have a relatively thin wall and consequently in

TABLE V

PROPERTIES OF ZIRCONIUM AND ZIRCONIUM ALLOYS

	Composition	0.1% Proof Stress tons/sq.in.	U.T.S. tons/sq.in.	Elongation on 2 in.
Commercially pure reactor grade zirconium		17.6	26.4	30
Zircaloy 2	1.5% Sn 0.1% Fe 0.05% Ni 0.1% Cr	22	31	27
Metropolitan Vickers alloy	0.5% Cu 0.5% Mo	25	33.6	22

this somewhat more massive form its rather indifferent resistance to CO_2 can be tolerated. Naturally, however, its use in such cases has stimulated work aimed at the development of zirconium alloys more resistant to CO_2 and most of this latter work has been done in this country. An early result of it is the alloy put forward by the Metropolitan-Vickers Company, which is a zirconium alloy containing 0.5% copper and 0.5% molybdenum, and which has been shown to have an appreciably greater resistance to CO_2 than either reactor grade zirconium or Zircaloy 2. The mechanical properties of zirconium and the two zirconium alloys mentioned are given in Table V, to which might be added the note that both the alloys have appreciably better creep strength at 450°C than the commercially pure reactor grade zirconium.

beryllium

extraction

There are four main stages in the extraction of beryllium from the ore, beryl, these being :

1. The ground ore is mixed with an alkali double fluoride, and roasted and leached to give a soluble alkali beryllium fluoride solution.
2. The fluoride solution is treated with caustic soda and this precipitates beryllium hydroxide which is then calcined to give the oxide.
3. The oxide then undergoes a treatment to convert it into a halide — a fluoride if the reduction to metal is to be by the thermal route and the chloride if it is to be by the electrolytic route.
4. There are two methods of reducing the halide to metal and there is at present some controversy as to which method produces metal with optimum properties for nuclear engineering requirements. The pros and cons of this controversy are complicated by the fact that so far the electrolytic material has been produced on a much smaller scale than thermally reduced material and there may, therefore, be the danger, not unknown in other fields, of not comparing like with like. The thermal reduction process involves reducing beryllium fluoride with magnesium at 1300°C. This reduction, which is carried out in a graphite crucible heated by high frequency induction, is exceptionally exothermic and very careful temperature control is necessary. The reaction mass is wet crushed and the beryllium metal is recovered in the form of pebbles. Alternatively, if the electrolytic route is followed, the chloride is mixed with sodium chloride to form the electrolyte and electrolysis is carried out in a nickel cell at a temperature of 350°C with a nickel cathode and a graphite anode. Beryllium is deposited in the form of flake which is water-washed to remove the chloride, washed with caustic soda to remove aluminium, etc., and finally washed in dilute nitric acid to remove as much beryllium oxide as possible.

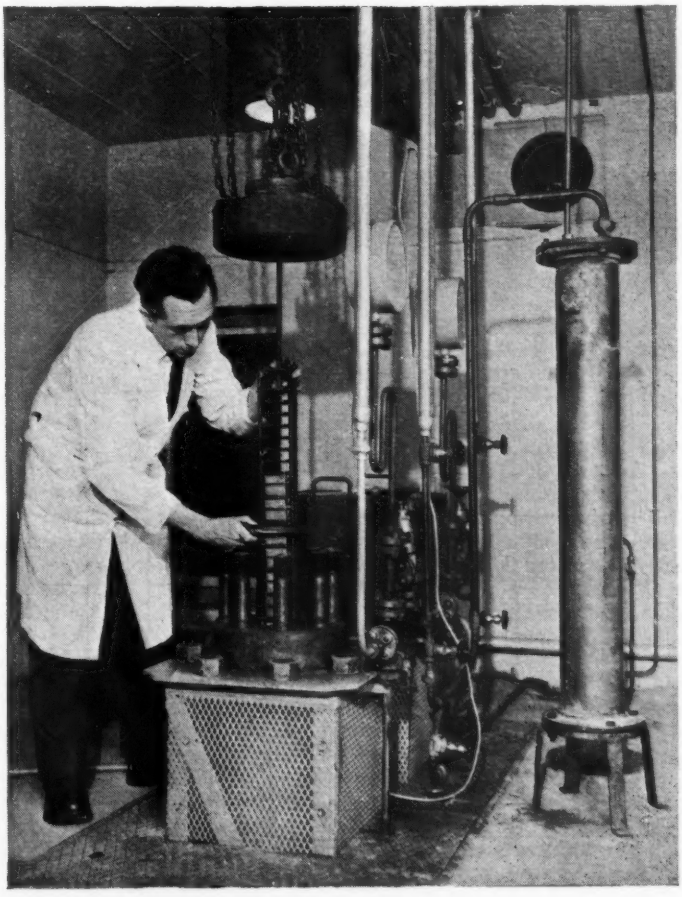

Fig. 10. Corrosion testing of zirconium in high pressure water : inserting specimens in autoclave

Comparison of compositions of typical flake and pebble in the reduced form indicates that the flake (electrolytic) is *at that stage* purer than the pebble (thermally reduced), as regards metallic impurities, but this in itself is not necessarily important *because both grades must be further purified by melting.*

melting

The melting process is carried out, not to consolidate the metal for further processing since, as we shall see, processing to wrought form is by a powder metallurgical route, but to effect purification. The melting process can, therefore, be regarded as an essential step in the overall extraction process.

Many techniques have been examined for further purification but vacuum induction melting is accepted as the most suitable commercial technique. Unlike the titanium melting and zirconium melting discussed previously, the consumable electrode technique is not used for beryllium since a suitable refractory, beryllia, is available for the crucible and melting is by high frequency, or medium frequency, induction under a vacuum of about 300 - 500μ. The melting point is quite moderate (1283°C). Some of the impurities, being heavier than the metal, sink to the bottom and are left behind in subsequent lip pouring. Volatiles such as fluorides, chlorides and magnesium metal, are drawn off, but as could be expected, there is no appreciable reduction in the beryllium oxide content. Graphite, steel, or cast iron may be used for the moulds.

As cast the metal is very brittle, due, not only to large grain size, but also unfavourable orientation of the grains on crystallisation. Attempts to refine the grain by the normal metallurgical approach of adding grain refining agents have not been successful and even if they had been, their possible effect on the important property of low neutron absorption capacity might have introduced difficulties.

health hazards

Before proceeding with the processing of the metal to wrought forms, reference must be made to the question of the toxic hazards of beryllium manufacture and processing, since the safeguarding against these hazards naturally influences the methods and techniques used.

Very briefly, inhalation of beryllium and its compounds in finely divided form can cause a serious lung complaint known as berylliosis. There is some evidence which suggests that this is in the nature of an allergy and that certain people are more susceptible than others, but unfortunately those allergic cannot with certainty be determined by known medical examination methods. Precautions must, therefore, be taken on the assumption that all are likely to suffer if exposed to the concentration of beryllium above a certain amount. Skin effects can also occur but these are much less hazardous. The solid metal is considered quite safe and, therefore, precautions are directed against safeguarding any operation involving beryllium or its compounds in finely divided form. Such operations as grinding and machining will obviously require special ventilating conditions, but it must also be assumed that in hot working operations there is the possibility that flakes of oxide or finely divided metal might be released and, therefore, precautions must also be taken for such operations.

All concerned in the processing of beryllium go to very great pains and expense to render the operations quite safe and in addition to special ventilating systems, a system of monitoring the atmosphere in any shop or laboratory where beryllium is present is an

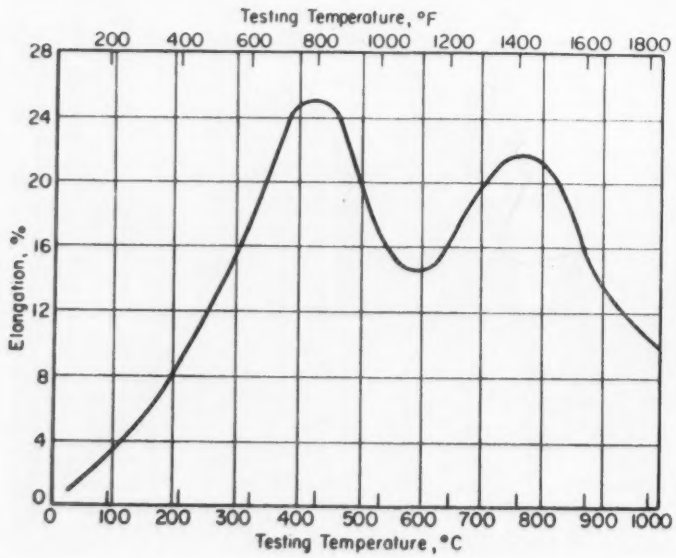

Fig. 11.
Effect of temperature on ductility of beryllium

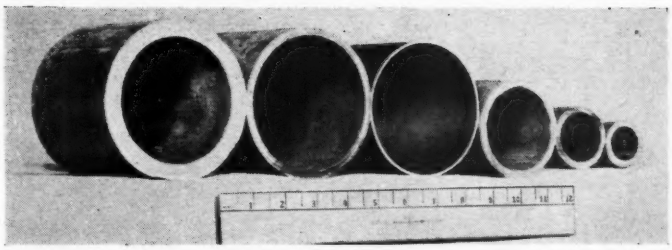

Fig. 12. Beryllium tubes produced by extruding the beryllium billet in a steel sheath at 950°C - 1150°C.
(Courtesy of The Brush Beryllium Company.)

essential feature of the work. The recommendations made by the U.S. Atomic Energy Commission are rigidly followed as regards allowable concentrations. Briefly these are that "in plant" concentration must never exceed a daily average of 2 microgrammes per cubic metre and at no time, even for a limited period, may personnel be exposed to a temporary concentration greater than 25 microgrammes per cubic metre. In addition, the monthly average of the atmosphere in the neighbourhood of any plants where beryllium is processed must not exceed 0.01 microgrammes per cubic metre of air.

In addition to very complete ventilating systems and monitoring arrangements, all personnel engaged in a plant or laboratory involving beryllium must change into special clothing on entering and shower thoroughly on leaving. The special clothing is laundered within the plant.

fabrication

Returning from this very important and essential digression to the matter of the further processing of the metal to wrought forms, the ingot is not processed direct as with most other metals.

The first stage after casting the ingot is to machine it to swarf or chip, which is then ground, in a ball mill or an attrition mill of the plate type, to powder — usually less than 200 mesh. This grinding is carried out in an atmosphere of argon or nitrogen to minimise contamination. The next stage is to consolidate the powder by compacting into the shape required for further processing. This compacting can be done under a variety of different combinations of pressure, temperature and time. Thus, compacting at room temperature can be done to produce a "green" compact of fairly high density (85%-90% theoretical) but the pressures required are of the order of 80 tons per sq. in. On the other hand, pressures as low as 100 lb. - 300 lb. per sq. in. are sufficient to produce similarly dense compacts at a temperature of 1050°C. At intermediate temperatures the compacting pressure varies accordingly, and the selection of the pressure-temperature combination can only be taken after full consideration of such factors as availability and cost of die materials and other economic factors.

A very interesting and recent development by the U.K. Atomic Energy Authority is to consolidate without pressure — what has in fact become known as pressureless sintering, and even higher temperatures are involved here.

Pressed compacts of the type mentioned above are then sintered under vacuum conditions at 1100°C - 1200°C and may then be further processed by machining, rolling, extrusion and forging. The properties of the pressed and sintered block are understandably improved by further working. Thus, the tensile strength of a hot pressed and sintered block is of the order of 20 tons per sq. in. with an elongation of 1% - 3%, but if this block is further hot rolled a tensile strength as high as 40 tons per sq. in. and an elongation of the order of 10% can be developed.

Although the room temperature ductility of the sintered compact is low, ductility rises appreciably with temperature (see Fig. 11), so that operations like rolling and extrusion can be readily carried out at an appropriately chosen temperature. Examination of Fig. 11 would suggest that 400°C would be a suitable hot working temperature because of the ductility peak at that figure, but the advantage of greater ductility has to be weighed against the lower tool pressures applying at higher temperatures. Assuming a properly health safeguarded plant, it would probably be safe to extrude at a temperature up to 700°C without misgivings that this would result in such a rise in the beryllium concentration as could not be taken care of by the special ventilating features of the plant. Study of the oxidation-temperature curve shows a very sharp increase in the rate of oxidation at 750°C and, therefore, if it is decided to hot work at, say, 800°C - 1000°C then it is usual to sheath the beryllium in a sealed mild steel sheath and then extrude or roll the composite workpiece. Mild steel has rather similar extrusion characteristics at these temperatures to beryllium and in addition does not alloy with nor contaminate beryllium. In addition to giving protection against increased beryllium concentrations in the atmosphere, sheathing also assists in preserving the surface, since beryllium tends to gall and seize locally when drawn or extruded through a die. Fig. 12 shows a number of beryllium tubes which have been produced by hot extruding at 950°C - 1150°C from steel-clad beryllium billets.

By these methods, extruded rod and tube and hot rolled sheet and plate have been produced and a large unit manufactured in the United States in such wrought beryllium is shown in Fig. 13. This is a reflector for use in a Test Reactor.

With regard to welding, it must be admitted that at present fusion welding cannot be recommended, although a very great deal of work on this subject is in progress. Some success has been achieved by

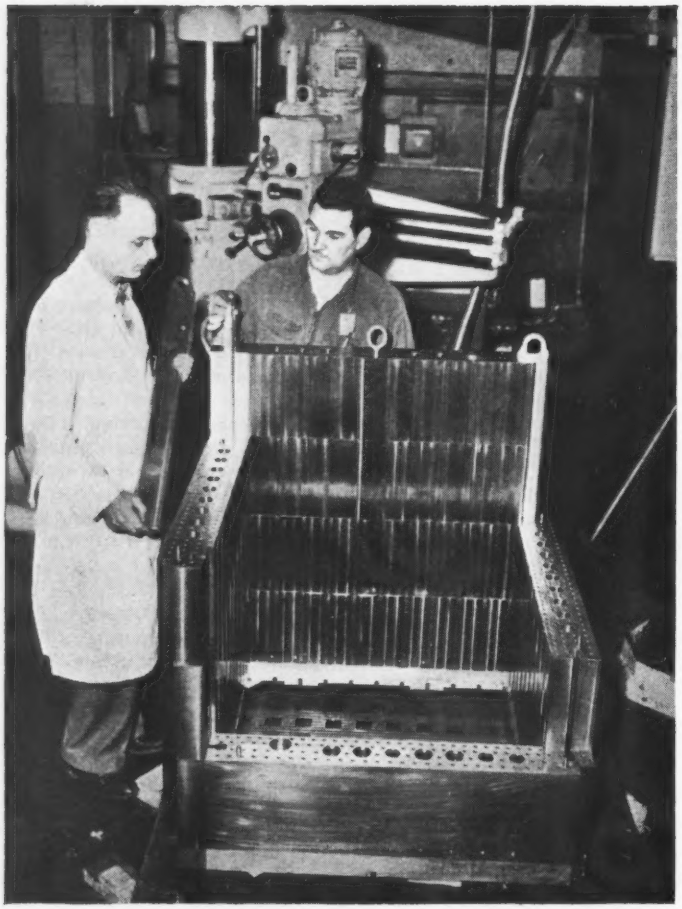

Fig. 13. Beryllium reflector unit
(Courtesy of The Brush Beryllium Company.)

pressure welding in an argon atmosphere or *in vacuo*.

Machining problems with beryllium are :

(a) those associated with the fact that at room temperature it is a brittle metal; and

(b) those associated with ensuring complete safety as regards non-dissemination of small particles of metal.

With regard to (a) it has been said that conditions suitable for the machining of cast iron are generally suitable for beryllium, although tool wear is probably higher. With regard to (b) a near-glove box technique, in which the work and essential part of the machine tool is enclosed in a covering or a shroud from which air and powder are continuously drawn off and evacuated to the plant filtering system, is the ideal and is probably essential for dry machining. At first sight, wet machining has attractions in that it would curtail the amount of disseminated dust, but care must be taken in regard to what happens to the contaminated cutting fluid, and there is the added complication of cleaning of the beryllium swarf to make it suitable for re-processing.

The writer trusts that enough has been said to indicate that beryllium is an important material in the nuclear engineering field and particularly so for the gas-cooled reactor, where its availability should bring about a considerable advance in performance and economics. Its use in fields other than the nuclear one is perhaps more problematic, although its combination of very low density (1.83), moderately high strength, and extremely high modulus (44×10^6 lb. per sq. in.) are clearly of interest in the aeronautical and guided missile fields.

It has, of course, had a small but important use for many years in the construction of X-ray windows. As an alloying element it is also well-known in the 2% beryllium-copper alloy and, indeed, most of the present-day production of beryllium is used for this latter purpose, although it should be added that it is not necessary to produce the metal itself in order to make beryllium-copper, this latter being produced by smelting with copper at the beryllium oxide stage.

some other new metals

An appreciable amount of attention is being devoted to NIOBIUM but whether its undoubtedly high potential will ultimately become of practical utility depends on whether certain deficiencies and difficulties can be overcome. The melting point is very high (2468°C), and the strength at high temperatures is outstanding. In addition the pure metal is very readily processed, being extremely ductile and capable of withstanding large amounts of cold deformation. Its neutron absorption property, whilst much inferior to zirconium, magnesium and beryllium, is reasonably low, and its corrosion resistance is very great indeed.

These properties make it a potential candidate for two quite different industrial applications :

1. as a canning material for a really high temperature nuclear reactor;

2. as a basis for an alloy for gas turbines and high temperature chemical reactions capable of being used at much higher temperatures than, for example, the Nimonic series of alloys, the discovery and development of which enabled the temperature barrier to be pushed forward appreciably in recent years.

With regard to (1) niobium has the advantage, only exceeded by tantalum and tungsten, of compatibility with uranium at temperatures of the order of 700°C and in addition would be resistant to the liquid metal coolants which might well be used in a highly rated high temperature reactor (tantalum and tungsten would not qualify for such service because of their high thermal neutron absorption).

With regard to (2) much research is in progress to overcome the deficiency which niobium has in that its oxidation resistance at temperatures above about 400°C is indifferent. The objective of the research in hand is to discover an alloy possessing to the maximum possible extent the high strength at temperature and workability of the pure metal, but having much greater oxidation resistance than the pure metal. Progress has been made in this search in that it has proved possible by alloying to increase the oxidation resistance of niobium at 1000°C several hundred times as compared with the pure metal, although at some expense in creep strength and workability. Even so, none of the niobium alloys so far reported is good enough as yet to warrant consideration as a turbine blade material at temperatures of, say, 100°C higher than is satisfactorily attainable with the present nickel-base alloys.

In common with most of the other new metals, impurities such as oxygen, nitrogen, hydrogen and carbon have a considerable influence on niobium and the statement made earlier that the metal is readily workable is only true if these impurities can be reduced to very low limits. Oxygen is the most detrimental as regards its effect on the workability of the metal and this perhaps is best and most simply shown by reference to Fig. 14, which shows the results by two different investigators of the effect of oxygen on the hardness of the metal.

Oxygen can be removed by heating in the presence of carbon at temperatures certainly above 1600°C and at very low pressures — lower than 10^{-5}. Treatments such as this have only become possible in recent years by the considerable advances in high temperature-high vacuum engineering.

The metal is embrittled by hydrogen, which can be removed by heating at 700°C at 1 micron pressure.

The chief metallic impurity is tantalum, which is chemically similar to niobium and is always associated with it in the ore. The necessity or not to remove tantalum depends on the ultimate use. If the metal or its alloy is required for corrosion-resistant or high temperature purposes only, there is no need

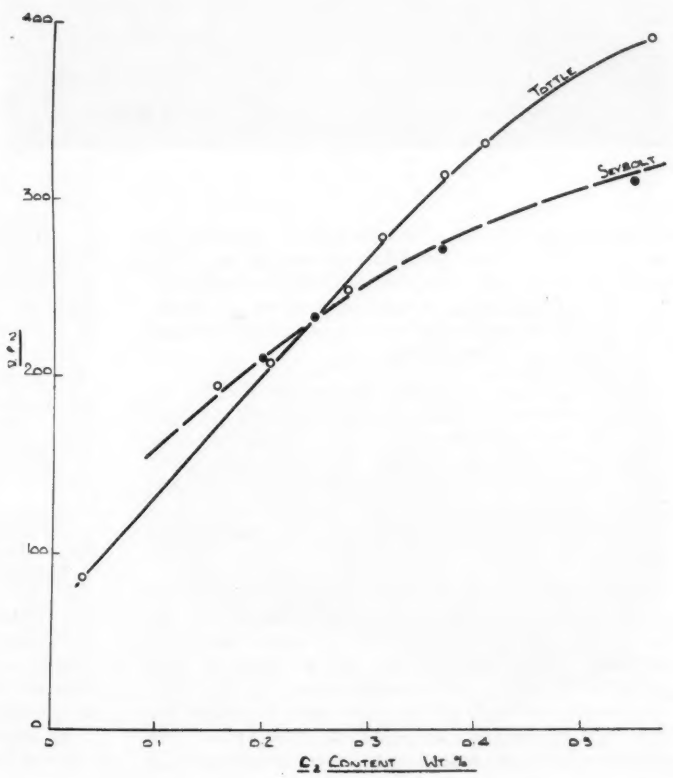

Fig. 14.
Effect of oxygen on hardness of niobium

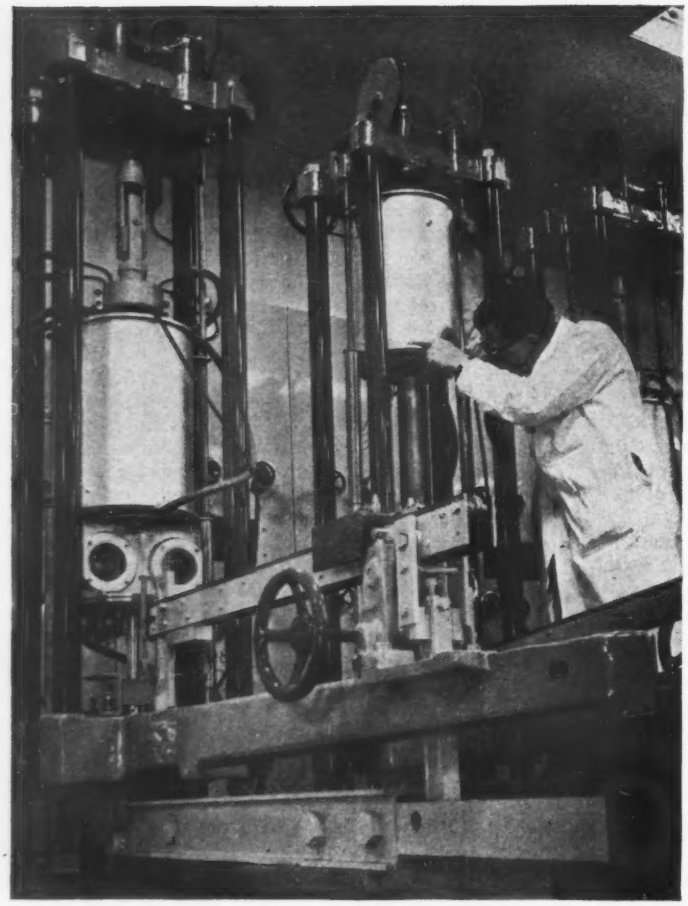

Fig. 15. Creep testing machine adapted for tests in argon or *vacuo*

to remove the tantalum, but for nuclear applications the presence of an appreciable amount of tantalum cannot be tolerated. The suitability of the tantalum-containing metal for non-nuclear purposes is important because naturally the cost of obtaining freedom from tantalum is very great.

In the present state of the research work on niobium alloys, it is often necessary to carry out high temperature creep tests without the serious complications which oxidation during the test would cause and, therefore, creep machines have been adapted so that such tests can be carried out in argon or *in vacuo*. Fig. 15 shows a creep testing machine so adapted.

The search for a new alloy having good strength at higher temperatures than are possible at the moment is not confined solely to alloys based on niobium. MOLYBDENUM as a base is also receiving attention in the same way, but the high temperature strength of the pure metal is rather less than that of niobium and it suffers from exactly the same weakness as regards oxidation resistance. In addition, molybdenum has the serious drawbacks of brittleness at normal temperatures and a relatively high ductile-brittle transition temperature, so that there is the necessity for very high temperatures in processing to wrought forms. Even so, considerable attention is being devoted in the United States to the development of a high temperature alloy based on molybdenum.

CHROMIUM might also be a base for such a high temperature alloy and as the price of the raw material is much lower than the other candidates it might at first sight be considered particularly attractive. However, it is seriously embrittled by such small amounts of nitrogen that it is difficult to envisage maintaining this impurity at the required extremely low level in normal commercial practice. It is possible that an alloy might be found more tolerant as regards nitrogen contamination, but no success or even near-success has yet been reported in this respect.

HAFNIUM, which was referred to earlier as a most undesirable impurity in reactor grade zirconium, is not without interest in the nuclear field for precisely the same reason as makes it an undesirable impurity in reactor grade zirconium, namely, its strong absorbing power for thermal neutrons. For this reason it has great possibilities for use in nuclear reactor control equipment. As already seen, it is a by-product of zirconium extraction and the metal itself is reduced from the chloride in much the same way as for zirconium. Its melting and fabrication to

the wrought form is very similar to that used for titanium and zirconium, the technology of which is now well advanced, so that if hafnium is required for control rods and the like there should not need to be an appreciable development effort.

Both the corrosion resistant and electrical properties of TANTALUM make it of interest in certain special applications, despite its very high cost. It has been commercially available for a longer period than most of the other metals referred to in this survey and, indeed, Fig. 16 shows a heat exchanger made in tantalum which has been in service for over 10 years in the United States. Its corrosion resistance is quite outstanding, since it is resistant to such strong corrodents as hot sulphuric acid, hot hydrochloric acid and hot phosphoric acid, in all cases over a wide range of concentrations. Its corrosion resistance is, in fact, generally superior to such metals as titanium, zirconium and niobium, all of which are themselves resistant over a very wide range of corrodents. Recently the importance of tantalum as a material for capacitors has arisen and the demand for the metal in the form of foil for this purpose is likely to become appreciable.

Neither space nor the writer's competence make it possible to say more about GERMANIUM and SILICON than that they now have an established place in the electronics industry for transistors and rectifiers. Here, again, with these two metals the main story with regard to their production is one of impurities, and it should be noted that for satisfactory performance in certain applications impurity levels of 1 in 10^9 maximum are required and achieved.

conclusion

In this very brief and far from comprehensive survey, the writer has attempted to show the growing industrial importance of those metals which were not in the industrial scene 10 years ago, but which have now reached or are approaching significant industrial importance. Their emergence in this way is due to the special requirements of recent engineering developments and their availability has been made possible by the progress in several branches of science and technology such as the advances in vacuum engineering, in powder metallurgy and in analytical techniques. In many of these very recent engineering developments the older metals, and improvements in them, will still play a vital role, but some of these recent developments can only come to full fruition by virtue of these newer metals. To paraphrase some famous words, it can be truly said that the new metals are coming to the rescue of the old, and that the combination of new and old metals greatly strengthens the designer's armoury and greatly extends his range of choice and selection.

(THE REPORT OF THE DISCUSSION ON THE PAPER COMMENCES OVERLEAF)

SELECTED BIBLIOGRAPHY

McQuillan, A. D., and M. K. "Titanium." *London, Butterworth's Scientific Publications,* 1956.

Kroll, W. J. "The Pyrometallurgy of Halides." Metallurgical Reviews (Institute of Metals), 1956, *1,* 291.

Kroll, W. J. "Titanium." Metal Industry, 1955, *87,* 63, 83, 105, 130, 147, 173.

Cook, M. "The New Metal Titanium." Journal of the Institute of Metals, 1953 - 1954, *82,* 93.

Inglis, N. P., and McQuillan, M. K. "A Progress Report on Titanium." Endeavour, 1958, *17,* 77.

Swainson, E., and Berry, R. L. P. "Production Problems of Titanium and its Alloys." N.A.T.O. Advisory Group for Aeronautical Research and Development. Report 95, April, 1957.

Rotherham, L. "Metallurgical Problems of Atomic Energy." Journal of the Institute of Metals, 1956 - 1957, *85,* 393.

Miller, G. L. "Zirconium." 2nd edition. *London, Butterworth's Scientific Publications,* 1957.

White, D. W., and Burke, J. E. (editors). "The Metal Beryllium." *Cleveland, Ohio, American Society for Metals,* 1955.

Williams, L. R., and Eyre, P. B. "The Metallurgy of Beryllium: its Nuclear Applications." Nuclear Engineering, 1958, *3,* 9.

McIntosh, A. B. "The Development of Niobium." Journal of the Institute of Metals, 1956 - 1957, *85,* 367.

Tottle, C. R. "The Physical and Mechanical Properties of Niobium." Journal of the Institute of Metals, 1956-1957, *85,* 375.

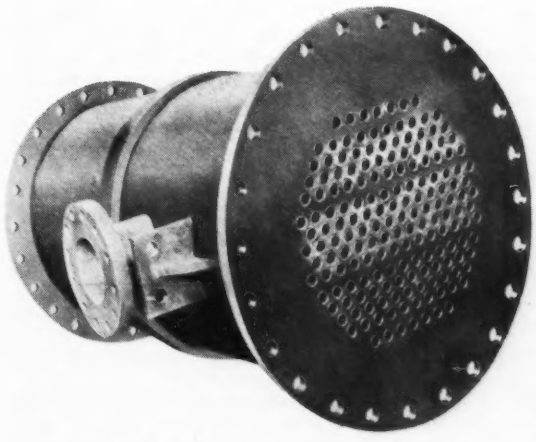

Fig. 16. Heat exchanger in tantalum
(Courtesy of Fansteel Metallurgical Corporation, Chicago.)

REPORT AND DISCUSSION

In the Chair:
Mr. G. Ronald Pryor
(*President-Elect of the Institution*)

THE **Chairman** welcomed all those attending the meeting and thanked the authorities of the University of Birmingham for providing facilities for the meeting and reception. This was the first time, he said, that a Viscount Nuffield Paper had been presented in Birmingham. It was the sixth of the series. The Viscount Nuffield Paper was one of the Named Papers which the Institution had inaugurated in order to honour distinguished people who had rendered it outstanding service. Lord Nuffield had been President of the Institution in 1937 - 39, and some members would recall the wonderful time he had given them at Cowley. He had worked very hard for the Institution and helped it most generously financially and in other ways. It had been through his generosity that the Institution had been able to establish the Production Engineering Research Department at Loughborough College, which had subsequently developed into the Production Engineering Research Association of Great Britain.

The first of the Nuffield Papers had been given by the Right Honourable the Lord Sempill, A.F.C.; the second, by Major-General W. A. Lord, of R.E.M.E.; the third, by Dr. G. H. Daniel, of the Ministry of Fuel and Power; the fourth, by Dr. Grey Walter, of the Burden Neurological Institute; and the fifth, by Lord Hives. Dr. Inglis, who would now present the sixth Paper, was a very worthy recruit to what he would no doubt regard as a very distinguished stable.

(*Dr. Inglis then presented the Paper which appears on pages* 219 - 237.)

The **Chairman** thanked Dr. Inglis for his most lucid exposition of an intensely interesting subject, and invited Dr. Matthew to open the discussion.

Dr. T. U. Matthew (*Engineering Director, Tube Investments Group Services, Ltd.*) said that it gave him very great pleasure to open the discussion on a Paper which, in the most effective way, gave up-to-date information on the progress which had been made in the United Kingdom in recent years in the development and application of some of the newer metals. They were all very indebted to Dr. Inglis, who had been very wise in limiting his treatment of what was a very rapidly growing field to a few only of the new metals. By this means, in spite of what he had said in his opening remarks about sacrificing depth to breadth, he had succeeded in taking his audience in some depth into the story of titanium production in the Metals Division of I.C.I., and the subsequent rapid development in the use of this metal.

The decision to go ahead with titanium production on the basis of using sodium as the reducing agent, which Dr. Inglis had described, must have been, and Dr. Matthew knew that it had been, a very difficult one to take at the time. His friend, Sir Arthur Smout, who was then I.C.I. Metals Division Director, had confided to him some of the problems involved in those years when a very large amount of money had had to be allocated to this development. In view of the capital expenditure on the plant and the technical hazards involved, Dr. Inglis and his colleagues must be congratulated on their technical insight and courage at that time in the face of the comparatively massive American advance along the magnesium route. They could now be congratulated also on bringing this piece of British enterprise to a really successful conclusion, which in the outcome had proved to be more economic in capital and operating costs than the American magnesium process. It was to be hoped that they would repeat this triumph in dealing with beryllium and some of the other new metals.

Titanium, like zirconium and beryllium, fell into the category of "strategic" metals, and it was a little disturbing to see the figures given in the Paper, which showed a British output of titanium of some 1,500 tons per year, compared with an American output of 30,000 tons per year, or 20 times as much. That was disappointing in spite of the population ratio of the two countries and the fact, which Dr. Inglis mentioned, that the Americans might have over-reached themselves a little. Economics, however,

came into the picture, and no doubt the economic success of the I.C.I. process would lead to a rapid build-up of British output when the demand justified it. When this expansion of output took place, no doubt a dramatic drop would take place in the cost and price per ton of titanium, which had been a semi-precious metal up to now, and in turn this would lead to a rapidly increasing demand. It would be of great interest to production engineers to see this progress, with the inevitable consequence of competition between low-cost bulk-produced titanium and the more common metals which they used today.

From the production engineering point of view, one attractive feature of titanium was that its metallurgy was closely similar to that of steel, and the transformations which it underwent during heat treatment should make it an equally versatile material. It was one which they could understand the more easily since they had been brought up on steel.

natural advantages

Leaving on one side the question of cost, which was offset in many applications by its wonderful corrosion-resistant property, titanium had a number of natural advantages over steel, and here Dr. Matthew spoke for the moment as a steel-maker and was looking at the potential dangers. In view of the low specific gravity and other characteristics of titanium, it would be of interest to know the extent to which the author had found it possible to develop applications of titanium alloys for duties involving large centrifugal forces in rotating machinery. Similarly, its magnetic characteristics made it of interest to the electrical industry. How far did the author consider that its use might be extended in this field also?

Zirconium and beryllium were two members of a fascinating range of new metals, metals which were almost completely new from the engineering point of view. In the nuclear power field, materials were subjected not only to the normal hazards of high stresses in a range of temperatures, possibly accompanied by fatigue conditions, but also to the effects of intensive irradiation. The author had indicated that the principal use of beryllium and zirconium was in canning uranium and other nuclear fuels, and this brought up the whole question of how far these newer metals would stand up to intense irradiation. It was nearly 40 years since Rutherford had first discussed the possibility of transmutation of metals in the modern language of nuclear physics, and today this concept had become almost an everyday consideration in the design of reactor "ironmongery". The questions which nuclear engineers had to answer included, for example, that of the time required for a piece of aluminium subjected to a thermal neutron flux of given intensity at room temperature to be converted to, say, 0.01% silicon as a result of neutron capture and subsequent beta decay. The production engineer might have to face this sort of question before long, and it would be of some interest to know something of the effect of prolonged irradiation upon the structure of these new metals.

Getting together in this group at the reception preceding the Nuffield Paper are (from left) Dr. Inglis; Mr. Maurice Cook, Chairman, I.C.I. Metals Division; Mr. Harold Burke, Vice-President Elect; and Mr. Bernard Jackman, Chairman of the Institution's Research Committee.

One point which emerged from the Paper was the peculiar characteristic of beryllium from a production engineering point of view, in that once it had been produced and fabricated it had superior strength properties in the longitudinal direction to those in the direction transverse to rolling and extrusion. It would be interesting to know whether or not any progress had been made in research in the direction of improving the transverse ductility of beryllium strip. Much of the advance in recent years was attributable to the use of advanced methods and tools of analysis. There had recently been some very elegant adaptations of the scanning electron microscope for X-ray spectrographic micro-analysis. Had the author made use of this tool in finding out where the impurities which were so undesirable in canning materials migrated to in the grains of the metal? The X-ray micro-analyser allied with the scanning electron microscope seemed to be an important tool to use in order to study the metallurgical aspects of this subject.

industrial adventuring

In conclusion, Dr. Matthew paid a sincere tribute to the author for his presentation of the Paper. The name Nuffield, he said, had always been associated in this country with the ideas of industrial enterprise, adventure and rapid growth, and latterly with research. In inviting Dr. Inglis to give the 1958 Viscount Nuffield Paper, the Institution had been very successful in finding a speaker whose industrial adventuring and practical success were very much in keeping with the title of this series of Papers.

Dr. N. P. Inglis, in reply, referred to the cost of the new metals and said that there was no doubt that with them adventuring (as it had been called) was

expensive. The capital cost was high and there were very high research and development charges, so that in the early stages, with only a relatively small tonnage, each ton had to carry a very high overhead for capital and for research and development. As the tonnage increased, however, the cost would inevitably come down. There was to some small extent a vicious circle, in that the cost could be reduced with greater use and there would be greater use if the cost was reduced. Somebody had to be bold enough to break that circle.

Dr. Matthew had mentioned the comparison with steel, and at first sight there seemed to be a comparison between the iron-carbon diagram and the titanium alloy system, but it was only at first sight. Dr. Inglis envied those who were concerned with steel, because they dealt with a delightful system with two phases, in one of which the carbon was relatively insoluble and in the other it was extremely soluble, so that life was made easy for them.

On irradiation effects, all that he could say was that a good deal of work had been done with the sort of fluxes likely to be encountered in nuclear stations, and generally the effect on most of the structures of metals was not as great as at first had been thought possible. Most of these metals had been in-pile tested to determine the irradiation effects of different neutron fluxes, and there seemed no cause for worry.

A great deal of work was being done on directional effects with beryllium, which was particularly prone to them. So far there had been no positive result of a kind which would make it possible to say "Do it in this way and you will get these results," but a great many data were being accumulated.

He agreed that a whole range of tools was necessary for the very refined analytical techniques which had to be employed in the nuclear field, and X-ray spectroscopy, polarography, photometry and other methods had to be enlisted, but not, in his view, the electron microscope, which he thought had been a rather disappointing tool. Everyone had thought that if it were possible to see things with a magnification of 40,000 it should enable a great deal to be discovered which could not be found out at a magnification of 2,000 to 3,000, but in fact it was possible to count on the fingers of one hand the metallurgical achievements of the electron microscope. No good metallurgical laboratory, however, could afford to be without one, because of the general feeling that one day it ought to be possible to see at $\times$ 40,000 what could not be seen at $\times$ 2,000.

Mr. G. Ronald Pryor (left), President-Elect, who took the Chair at the meeting, chats with Professor N. A. Dudley, Department of Engineering Production at the University of of Birmingham; and Dr. T. U. Matthew, Engineering Director, Tube Investments Group Services Ltd. (right).

Mr. Harold Burke (*Vice-President Elect*) said that Dr. Inglis had told a fascinating story. Mr. Burke had found it of particular interest because it had revealed some of the reasons for the high cost of these precious metals. Dr. Matthew had touched on the economic side, and after the brilliant presentation of the Paper and an equally brilliant opening of the discussion by Dr. Matthew, Mr. Burke wondered why he had allowed himself to be persuaded to be the second speaker. He was not competent to deal with the metallurgical side of the subject. The Paper dealt in great detail and in a most interesting way with the resistance of the new metals to corrosion and to high temperatures, but Mr. Burke felt that questions on those matters could best be left to the nuclear power engineers and the aircraft designers. There were, however, two questions which he would like to put.

One concerned cost. They looked forward to the day when these precious metals would be no longer precious but would become the common or garden tools of industry, in daily use. In Birmingham, in the middle of the motor industry of this country, one question of concern to him was the elaborate use of chromium plating on motor cars. For years he had been conducting a campaign to do away with this chromium plating, which lasted only for a very limited time. There were, of course, answers which production engineers were applying, but he looked forward to the day when the new metals could be used commercially. Could the author hold out any hope that one day motor cars might be adorned with metals in this category? It would add to the prestige of British industry if they could be so used and employed elsewhere where decorative effect was important as well as corrosion resistance.

Secondly, on the question of economics in relation to production engineering, the author had touched on machinability. It would be interesting to have more information about the machinability of some of these materials. Many engineers present had probably had more experience than he had, but Mr. Burke had heard from time to time of difficulties experienced in machining these metals. Perhaps the author would say something more about that.

Dr. Inglis, on the question of cost, replied that for many years engineers had relied on a relatively few metals the price of which had varied between 4d.

and 5s. per lb., so that many engineers had become conditioned to the 4d. - 5s. range and regarded anything beyond it as " out ". It was necessary, however, to look at the matter rather differently. He did not think that it mattered how much something cost so long as it was possible to get a return on the money expended, because that was what one looked for. Beryllium for nuclear power stations was very expensive, but if the cost justified itself because, through the ability to produce power more cheaply, a return was obtained on the capital cost of using beryllium, then beryllium was economic. It was from that point of view that the question must be looked at.

The idea of using beryllium, zirconium and titanium on motor cars instead of chromium plating was an attractive one, but he feared that those metals were not likely to get into that range. There were some inherent reasons for that. Their very virtues were difficulties in some ways so far as making them cheaper was concerned. He would like to see their extended use but found it difficult to believe that it would be extended as far as that, though he agreed with what Mr. Burke had said about chromium plating.

On machinability, in the early days it had been said that titanium was very difficult to machine, but that had been due largely to impurities in the titanium. With a different method of melting from that now employed there could be carbide particles in the titanium, and titanium carbide was itself a very good tool material, so that it was hard luck on the tool that met it. In that way titanium had got a bad name; but, given robust machine tools and freedom from chatter, titanium was fairly readily machinable. The machine shop must never be told that it was a new and special material, or it would be found very difficult, but if it was just given to them to machine there would probably be no trouble.

Beryllium was in a different position, because it was a brittle material, so that in addition to the health hazard difficulty (which could be easily overcome, though overcoming it reduced productivity to some extent) there was the difficulty which was always found when machining a brittle material. Zirconium was much the same as titanium so far as machining was concerned, and, from the little that they had done, the machining of niobium seemed to be very straightforward. Machinability was unlikely to be a major obstacle or a major cause of cost, although other things would be.

Mr. John A. Grainger (*European Industrial Consultants, Ltd.*) congratulated Dr. Inglis on the masterly way in which he had dealt with a very difficult subject — difficult, at any rate from the point of view of making it intelligible to production engineers. An interesting point brought out by the Paper was that these " new " metals were not really new at all but had been known for 100 years or more, though they were only now beginning to be used. It was not that the metals were new, but that the industries which used them were new, and were finding uses for which the metals had been waiting for the last 100 years.

Dr. Inglis mentioned that the chemical, petroleum, power and nuclear engineering industries all presented problems of their own. At one time those problems had been separate and distinct, but at the present time Mr. Grainger did not think that they were so distinct as they used to be. Industries were coming closer together by the materials and basic principles of one industry being used in others. The aircraft and marine engineering industries, for instance, were becoming tied up with the nuclear power engineering industries because the gas turbine was getting into the nuclear energy field and research was going on into a nuclear-powered aeroplane and into the use of nuclear power for ships. These developments provided a challenge not only to the metallurgist but also to the production engineer, and it was for the production engineer to accept that challenge and find a solution.

A good deal of emphasis had rightly been given in the Paper to the production and fabrication of titanium. Some time ago, Mr. Grainger had been privileged to witness a demonstration on an experimental basis of a method of melting titanium, which was not mentioned in the Paper. It involved the use of a water-cooled copper crucible and the feeding into the crucible not of compacts such as the author had mentioned, but of pellets of titanium. The arc was struck on the pellets which became molten and formed a pool. As the pool rose in the crucible, due to variation in arc voltage the electrode was withdrawn to maintain arc length and the outer layer of titanium froze on to the water-cooled copper crucible, so that virtually the titanium was being melted in a titanium crucible. The protagonists of this method claimed that it would produce far purer titanium than any other method. It would be interesting to have the opinion of Dr. Inglis on that, and to know whether or not he thought that it would ever be a useful method of producing titanium metal.

On another aspect of the fabrication of titanium, extrusion, had any use been made of the practice of nickel plating the billet to get better extrusion properties? Mr. Grainger had in mind, for instance, the method used by many producers of gas turbine blades for use in aircraft engines and commercial engines, for forging to tolerances of, say, $\pm$ 0.002 in. on the blade wall.

Another point on the fabrication of titanium was the author's reference to the lack of ductility in the welded joint due to the reactions taking place within the weld itself. Was this lack of ductility entirely due to those reactions and confined entirely to the weld metal, or did it extend to the heat-affected zone adjacent to the weld metal, as with high strength alloys such as the Nimonics?

Zirconium and beryllium seemed to have contrasting advantages for use in nuclear reactors, zirconium for use in the water-cooled reactor and beryllium for use in the CO_2-cooled reactor. One was tempted to wonder whether or not a

marriage of convenience could be arranged there, or would this be a case where the alloying of two metals, each with distinctive properties in one field, gave an inferior material when they were combined?

On the purification of zirconium, a process which at first sight seemed as though it might be useful was the vacuum deposition process. Could not this method be used for purification by closely controlling the vaporisation temperature only on the metal which was wanted as a pure metal, leaving the impurities behind?

This led him to another problem which production engineers had to face, that of welding. Here a question which arose in other cases seemed to be one which might arise in the welding of zirconium and beryllium materials and alloys, namely, whether or not there was any loss due to burn-out in the arc of constituents of the metal. With a pure metal there should be no constituents, but some must always be put in to get an alloy. Taking the analogy of Nimonic 100 or 105, a different rod had to be used for welding because there was burn-out of cobalt and aluminium in the arc, so that a rod of different constitution had to be used.

What was said in the Paper about the health hazards with beryllium was very interesting. It was interesting to find that the health hazards with beryllium, both toxic and dermal, were parallel with those in the plastics industry when using epoxy resins in combination with an amine hardener. There seemed to be a case for people in both industries getting together to solve a problem which had been attacked from two different angles.

Finally, most of the new metals and alloys had one object in view, to provide people such as aircraft engine manufacturers with materials of very high strength at high temperatures, and at those temperatures to have a very low creep ratio. The author and his research workers and metallurgists were asking production engineers to machine the unmachinable and forgers to forge the unforgeable. How long would this have to go on before they found that they could not use it at all?

Dr. Inglis, dealing first with the melting of titanium, said that Mr. Grainger had described the first method to be used for this purpose, employing not the consumable electrode but a fixed electrode, of either tungsten or carbon. One put a little titanium in the bottom, struck the arc with the fixed electrode and by continuously feeding pellets built up an ingot, withdrawing the fixed electrode as one did so. There were a good many difficulties with that method and it had now been completely superseded. The chief difficulty was that it did not produce a pure material, because either carbon or tungsten was incorporated in the ingot. It might be only a small amount, but one could not afford to have it. It was very nearly impossible with Kroll titanium or with sodium-produced titanium to get an absolutely inert base material. There were volatiles present and there was a little splashing which caused molten metal to come in contact with the electrode. Secondly, the method which Mr. Grainger described was always operated in argon and was not easy to operate in vacuum, and generally vacuum melting was now regarded as very much better. Thirdly, the rate of production of ingots was very much better by the present method. Dr. Inglis was sure that the method described would not supersede the present one, because the present one had superseded it.

On the extrusion question, he had had no experience of nickel plating, but many things had been tried either to act as a lubricant or to hold the lubricant there. Nickel plating might be an effective aid, but he did not know the answer.

Mr. Grainger had misquoted what was said in the Paper about weld metal. Dr. Inglis had been dealing with certain of the heat-treatable alloys and had said that there was a lack of ductility which he attributed to reactions which occurred during cooling. He had been referring to those reactions associated with the change of state brought about by heat treatment, so that the lack of ductility was due to the fact that the state of heat treatment which gave the maximum ductility was upset by welding. It was not in the weld metal that that was done but adjacent to it.

On the question of a marriage of convenience between zirconium and beryllium, it must be borne in mind that one was dealing with two different things. One was corrosion-resistant to water and the other to CO_2. Efforts were being made to study the alloying of zirconium to make it more resistant to CO_2 and to bring zirconium into the picture more as a possible material of construction in a gas-cooled reactor, but it could not be said that because one metal had one set of properties and the other another, the alloy of the two would have a nice composite set of properties. He did not think that it would work out in that way.

The method of refining which had been suggested — it was right, he agreed, to describe it in that way — was one which even laboratories could scarcely afford to use, so that such methods had a long way to go before becoming production methods. They might become production methods one day, but that day was a long way off.

Mr. Grainger's analogy of the health hazards in plastic industry with those of beryllium was interesting, but only a medical man could say whether of not there was a true analogy between the two cases.

Mr. Grainger's last point, and a very good one, was that materials which had very great strength and very great resistance to deformation at high temperatures would be very difficult to forge. Presumably the answer must be that if they were intended to be used at a certain temperature, then for massive deformation they must be taken to a still higher temperature. If niobium or niobium alloy was to be used at 1,100°C, hot forging might have to be done at 1,300 - 1,400°C.

Mr. A. J. Catton suggested that most of the uses of these new materials so far mentioned had been for containers, bulkheads and so on. Was it possible to envisage their use for moving parts or where rubbing

surfaces were involved? What was their resistance to abrasion?

Dr. Inglis replied that for moving parts under centrifugal conditions — not abrasion or contact — a material of high strength and low specific gravity came high in the list of desirable materials. The normal trick in engineering design when the stresses were considered to be too high was to make the part thicker, but that could not be done in the case of a centrifugal stress, because it would make the stress higher. For centrifugal parts, therefore, materials of high strength and low specific gravity were very suitable. An instance was afforded by turbine blades, for which titanium was frequently used.

So far as abrasion was concerned, titanium was very abrasion-resistant from some points of view, but it had a tendency to stick or seize if in very tight contact. On the other hand, it had been used in a limited way for certain steam turbine blades where erosion had been very considerable by water droplets in the steam, and there a titanium alloy, after a long series of tests, had come out very well. It had not been so good as Stellite and very hard alloys of that type, but it had an abrasion resistance commensurate with its hardness, which was about 300 D.P.H. Much depended on the type of abrasion. For resisting ordinary abrasion, such as bombardment by water droplets, it was as good as its hardness would suggest, but in a gear-tooth case it might stick and seize, even if the mating gear was titanium. It might be possible to devise a surface treatment to get over that difficulty.

Mr. Russell, referring to the corrosion resistance of titanium, said that at one time he had been concerned with marine engineering, and in marine work corrosion was Enemy No. 1. Titanium, therefore, would appear to be a very suitable material to use in marine engineering. Was it possible to foresee its application to the plating of ships in the future? Cost would be the bugbear there, but could that difficulty be overcome in the interval by metal spraying or something of that kind?

Dr. Inglis said that titanium had a strong, and what might be described even as fantastic, resistance to corrosion by sea water, even in conditions of impingement and deposit and other features which caused trouble with other metals, and he was sure that in the marine field it must have considerable value; but, as had been said, the bugbear was the cost. Optimistic as he was about the future of titanium, his imagination boggled at the idea of ships' hulls in titanium, though he hoped he was wrong. On the subject of spraying, forgetting for the moment all about titanium, did anyone know of an instance where sprayed or deposited coatings in any metal had stood up to *really severe* corrosion? Aluminium was very resistant to concentrated nitric acid, but would anyone use a mild steel tank sprayed with aluminium to hold strong nitric acid?

The President-Elect (second from right) has a word with Dr. Inglis, Mr. Jackman and Dr. Maurice Cook.

Mr. R. J. Garland (*Rubery, Owen & Co. Ltd.*) said that in the nuclear engineering field it was necessary to remove the fuel elements from reactors at reasonable intervals and to refine them to remove fission products. If the beryllium can was removed, would it be possible to rework the metal into new cans, or would it be necessary to supply virgin metal for cans? Titanium scrap at the moment was almost valueless, as it could not be reworked into metal. Would beryllium scrap be in a similar commercial position?

A previous speaker had mentioned the difficulty of working creep-resisting alloys. Ultimately, creep-resisting alloys would have to be used to cast.

Dr. Inglis, on the question of reworking, said that having made the fuel can, whatever the material, it went into the nuclear reactor, and it must come out periodically and go right back to the beginning of the process again. The cans would also be contaminated.

Mr. Garland: Can they be worked back in?

Dr. Inglis: Not directly, no. They would have, he said, four or five years' life, and then they would be worked back in.

Mr. Garland said that titanium could not be worked back in.

Dr. Inglis remarked that that point should be cleared up. With scrap titanium, it depended how the scrap had been made. If his firm had made the scrap themselves they might be able to use it again, but if somebody else had made the scrap they would be doubtful about it. (*Laughter*) That might sound cynical, but if somebody else had made it and it was badly oxidised, then when they tried to remelt it they would be in trouble, but if they were sure that it could not have been contaminated in any way they could probably use it. Scrap was not just scrap; one's own and somebody else's and some third person's were quite different metals.

Mr. Durrant asked what, if there were any, were the advantages of using titanium as compared with stainless steel. In the high-temperature gas-cooled reactor, he said, where it was hoped to use beryllium to can the fuel instead of stainless steel, the temperature would be 600°C. and the can temperature 100°C higher. The UO_2 fuel had little strength compared with ordinary uranium fuel. What was the comparative strength of stainless steel and beryllium at these high temperatures?

Dr. Inglis agreed that titanium had yet to find an outlet in the nuclear field proper. Vast quantities of stainless steel were used at present in the extraction and production of uranium, but stainless steel as a canning material had a great deal against it. The capture cross-section was extremely high, and stainless steel was hardly in the running for the gas-cooled reactor; it would be in the running only if one were prepared to sacrifice neutron economy and make the stainless steel so thin that there would be production difficulties.

The temperatures which had been mentioned surprised him. He understood that a temperature of 700°C was referred to.

Mr. Durrant: A reactor temperature of 600°C. would mean a temperature of 700°C for the can.

Dr. Inglis said that at that temperature, comparing stainless steel and beryllium, he thought that stainless steel would have an advantage as regards strength, but it would be dropping rapidly, and at a higher temperature there would not be much in it. At 600°C. the latest stress-rupture figure for beryllium was $1\frac{1}{2}$ tons per sq. in. Stainless steel would beat that, though by how much he was not certain, but above that temperature its advantage would fall rapidly. It was necessary to strike a balance. Stainless steel would get a bad mark for neutron economy but a good mark for cost, but there might be difficulty in making it into very thin tubes and there might be secondary troubles such as buckling.

Mr. P. J. Shipton (*Chairman, Wolverhampton Section*), on the question of spraying metal, pointed out that spraying was done to prevent corrosion and that it was possible to get a better job than the original by metal spraying on a bearing surface. He asked whether it was possible to spray titanium.

Dr. Inglis said that he had emphasised severe corrosion, which was often experienced in marine work. Titanium could be and had been sprayed. Anything which could be obtained in the form of wire could be sprayed. Care had to be exercised, because there was a danger of getting a badly oxidised coating. It might still be protective, but it might be porous, as most sprayed coatings were. He did not intend to deprecate spraying, which could be extremely useful in many circumstances, but Mr. Russell had been concerned about severe corrosion.

Mr. E. Percy Edwards (*Member of Council*) invited Dr. Inglis to comment on machinability, and in particular the drilling of comparatively accurate small holes, say $\frac{3}{16}$ in. - $\frac{1}{4}$ in.

What type of tool would he advocate? Would he use high-speed steel or tungsten-carbide drills, and finish by reaming, and, if the latter, would he advocate using high-speed steel or tungsten tools?

Dr. Inglis, assuming that the question referred to the machining of beryllium, said he had not a great deal of information about it, but emphasised that the reasonably accurate drilling of small holes had to be done, because of the design requirements of the gas-cooled type of reactor. The tool wear was likely to be quite considerable, so that the use of high-speed tools would be necessary and probably tungsten-carbide would be advantageous. It had been suggested that the machinability of beryllium should be compared with cast iron, apart from the much greater tool wear.

Mr. Harold Tomlinson, (*Chairman of the Midlands Region*) in proposing a vote of thanks to the author, said that seldom in the history of the Institution had such an enlightening and interesting Paper been presented. The Midlands Region were fortunate in being able to offer this contribution to the Institution and in having the Paper presented under the name of Viscount Nuffield. The Paper had led to a most interesting discussion, beginning with a valuable contribution from Dr. Matthew. On behalf of everyone present, he thanked the author very much indeed. (*Applause*)

The meeting then terminated.

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THE PROBLEMS OF PRODUCTIVITY IN THE COTTON TEXTILE INDUSTRY*

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During the War he served from 1939 to 1946 as a Major in The Royal Northumberland Fusiliers. He is a graduate of the Military College of Science and from 1944 - 1946 was seconded to the Chief Engineer's Department, Armaments Design Department, Ministry of Supply, as Chief Design Officer in Small Arms.

Mr. Ormerod is Vice-President of the British Association of Textile Works Managers, and a member of numerous technical committees. He has written extensively and lectured at several trade conferences on the mechanical processing of textiles. The Paper published here was presented to the North Western Region of The Institution of Production Engineers on 27th April, 1959, at the College of Science and Technology, Manchester.

THIS Paper is intended to examine the problems of productivity in the Lancashire cotton textile industry. As production engineers, we believe that manufacturing problems can be effectively solved by application of the technology and techniques of production engineering, regardless of the character of the production operations or the end product. Outside this particular Institution this view would be considered to be not a little contentious. Certainly few spinners and manufacturers would accept that their mills could be run efficiently other than by someone with a lifetime's experience in the industry. This insularity is, I think, peculiarly applicable to the United Kingdom industry. Both in Europe and U.S.A., executives move freely between textiles, chemicals and automotive products, with the result that ideas tend to coalesce, and sound practice tends to penetrate radially, rather than linearly. Under these conditions production engineering techniques become a powerful catalyst to change along the whole industrial front, and not only in the metal-working industries.

It is true, of course, that special problems do exist which have discrete significance to particular industries. This follows directly from the fact that we all work within an industrial framework delineated by political considerations, and that the size and shape of this frame delineates our area for manoeuvre. Occasionally, politicians have not been satisfied with providing the frame for particular industries, and have stepped outside the business of government to assume the responsibility for painting the picture. Clearly, therefore, although different industries are faced with common problems, their relative significance varies greatly.

* It should be noted that the recent announcement regarding Government aid for the cotton textile industry was made while this Paper was in course of publication.

TABLE I
CHANGES IN CAPACITY, LABOUR FORCE AND OUTPUT IN THE COTTON TEXTILE INDUSTRY

	1913	1958
Cloth production/annum (million yds.)	8,050	1,600
Workers employed (spinning, weaving and finishing)	620,000	280,000
Looms in production	786,000	270,000
Spindles in production (millions)	55·6	20·0

As these problems have a direct bearing on the technical and managerial problems with which this Paper is concerned, it is desirable that they should be briefly outlined. Furthermore, as productivity is a dynamic conception dealing with trends, it will be necessary to examine briefly the historical background to these problems insofar as they affect the development of the technical argument.

a short review of changes in productivity

The period between 1750 and 1912 was one of almost continuous expansion for the cotton textile industry. Admittedly there were difficulties to overcome, but these only proved to be minor checks to be followed by still more rapid expansion. At the turn of the century the Lancashire industry led the world in the mechanical manipulation of fibres, and controlled 80% of the world's export trade in cotton textiles. During this period of expansion productivity increased at a high rate. In spite of shorter hours worked, there was a tenfold increase in output from 1830 to 1912, with only a twofold increase in the labour force. After considering the change in hours worked, this shows a compound rate of increase in productivity of slightly less than 2½% per annum. By any standards this was a very considerable technical and administrative achievement. The decline, however, was even more spectacular that the expansion, as shown in Table I. These figures show the great reduction in capacity and output which has taken place during the relatively short period of 45 years*.

In general terms, productive capacity and labour force have declined by about 60% and 55% respectively, and production by very much more. As the character of the output has changed materially over this period, it is unsafe to draw conclusions on productivity from these crude data, but it can be said with certainty that unless the product-mix has increased in complexity over this period to such a degree as to require 20% more labour hours per unit of output, then there has been no improvement in productivity.

The post-war statistics are of considerably greater interest as they remove the substantial effect of long-term change in product-mix, the character of the industry having been reasonably stable in this respect since 1946. Table II shows the post-war productivity trend in spinning and weaving.

* A Glossary of Terms is given at the end of the Paper.

TABLE II
Productivity trend in spinning and weaving

	Spinning				Weaving			
	Wkly. av. single yarn prodn. (mill. lb.)	Estimated average count	App. Av. No. at work in spg. mills (000's)	Wkly. av. output per head (lb.)	Wkly. av. cloth prodn. (mill. yds.)	Av. No. at work (000's)	Wkly. av. cloth output/head (yds.)	Wkly. av. yarn consumption (lb.)
1946	13·42	26·9	84·2	159	35·07	86·5	405	125
*1947	13·55	27·2	89·1	152	35·90	93·6	384	124
1948	16·27	27·0	101·0	161	42·61	106·2	401	132
1949	17·05	26·9	105·4	162	45·95	112·9	407	131
1950	18·14	26·1	109·1	166	49·76	118·9	419	137
1951	18·60	25·9	111·8	166	51·69	121·5	425	140
**1952	13·11	25·4	90·4	145	39·95	104·6	382	123
1953	15·92	25·7	100·3	159	45·13	110·1	410	134
1954	17·06	25·5	104·4	163	48·23	113·5	425	138
1955	14·84	25·1	94·9	156	42·84	105·2	407	133
1956	14·17	25·2	89·6	158	39·80	96·9	411	134
1957	14·68	24·5	89·8	163	39·02	93·6	417	142

* Working week reduced from 48 to 45 hours.
** Annual holidays increased by 4 days per annum.
Source: The Cotton Board Statistical Department.

It is apparent that there has been little improvement in productivity. Considering spinning first, there is only a difference in production of 2 lb. per head per week between 1948 and 1957, and the average count has fallen from 27.0 to 24.5 in the same period. When adjusted for reduction in average count spun, this corresponds to a net loss. Even during the period of expansion, the average weekly output per head never exceeded 116 lb. of yarn of an average count of 25.9. On the manufacturing side, the picture is not markedly different. Although there was a corresponding increase in yarn consumption per head from 132 lb. to 142 lb., this is partially accounted for by changes in cloth structure. The increase in yardage woven per head was only some 4%. By any standards this is a disappointing return for 10 years' technical effort. It is even more disappointing if one considers that during the same 10 years there have been greater advances in the mechanical processing of textiles than during any period of comparable duration in the industry's history. It also compares very unfavourably with the 2½% per annum compound rate of increase in productivity which was steadily maintained for 80 years before the First World War.

The efforts of European textile industries to improve their technical economies were demonstrably more effective than those of the United Kingdom industry. Between 1950 and 1957 the output per head in spinning mills in Western Germany, Belgium and France increased by 56%, 39% and 59% respectively, compared with 3% in the United Kingdom. During the same period the output per head in weaving mills in Western Germany and France increased by 30% and 66% respectively compared with 4% in the United Kingdom. The trend of these changes is shown more clearly in Figs. 1 and 2. Lest it be thought that productivity in the United Kingdom mills started at a much higher level, with less potential for improvement, the output per head in lb. per hour in spinning in 1957 was 228, 246, 237 and 163 in Western Germany, Belgium, France and the United Kingdom respectively. The corresponding average counts spun were 24.0, 20.7, 22.6 and 24.5.

It is now proposed to examine some of the factors which are considered to be responsible for this persistent lack of technical progress in the Lancashire textile industry.

some non-technical impediments

It can be said with some degree of certainty that the crippling contraction shown in Table I could not have been avoided, even if the highest possible standards of administrative and technical practice had been in general use during this period. The industry was probably too slow in recognising the growing potential of Asian domestic and export production, and this doubtless made the contraction less orderly and more wasteful than might have been the case. The price differentials, however, were too great to neutralise by the highest standards of technical competence then possible, and although the

COMPARISON IN PRODUCTIVITY TRENDS IN SPINNING AND WEAVING BETWEEN THE UNITED KINGDOM AND OTHER EUROPEAN TEXTILE INDUSTRIES

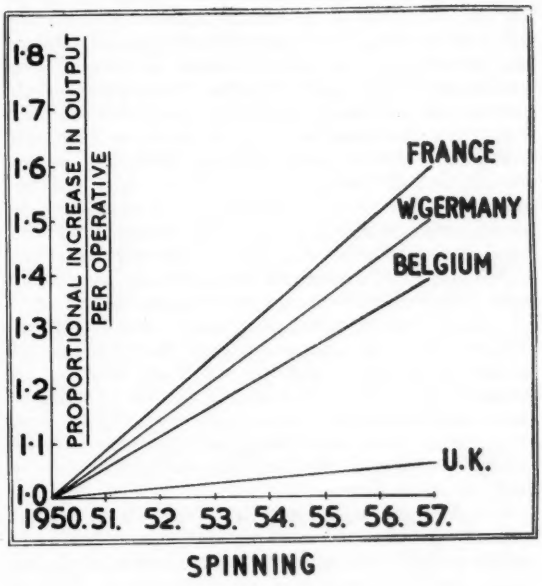

Fig. 1.

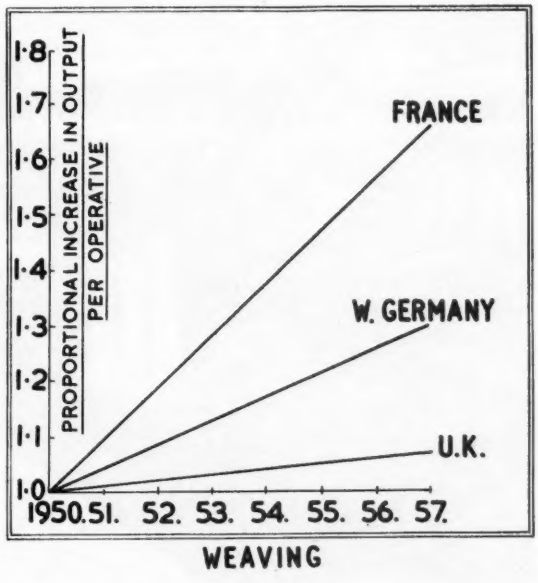

Fig. 2.

industry had clearly lost its early momentum for invention and innovation, these contributory causes could only be regarded as of second order significance. During the Second World War the industry's labour force was concentrated. It was also compelled to devote its attention to a small range of highly rationalised products with relatively small technical content. This was diametrically opposed to the only policy which offered any degree of long-term stability and remunerative operation — that was, and is, to manufacture high quality products requiring a high standard of technical knowledge and ability.

In 1945 the industry appeared to have a chance to capitalise on its knowledge and skill. The world was starved of textiles, and world capacity fell far short of requirements. A lengthy period of steady and remunerative trading clearly lay ahead, and the Lancashire industry was given a breathing space to re-equip and reorganise to meet the inevitable, highly competitive post-boom conditions. There were, of course, many difficulties, such as the supply position for new machinery and the shortage of skilled labour; but these are, after all, the sort of problems with which professional and virile management can reasonably be expected to cope. The figures in Table II show the disappointing results of the industry's post-war efforts to increase its productivity and, *per se,* its competitive ability.

The industry has, for many years, been fundamentally defensive in outlook. The majority of the industry's leaders show more interest in trading agreements and artifices to control competition, than in its organisation and technical economy to meet it. The Anglo-American Productivity Reports on the various sections of the industry showed comparable disparities between United Kingdom and U.S.A. levels of productivity to those existing in other industries, but more effort was expended in excusing and attempting to justify these disparities than in trying to understand the reasons for them, preliminary to making a determined effort to achieve the maximum possible improvement consistent with the resources available. The various trade associations, which represent the horizontal tiers of the industry, epitomise this defensive thinking. In general, these organisations tend to be more concerned about the progressive firms than the inefficient. The former have to be carefully monitored lest their more advanced technical methods permit the payment of higher wages, which would prove an embarrassment for the less technically competent. Furthermore, and this isn't really surprising, the latter are generally the most articulate and enthusiastic members of these associations. In addition to the atrophying effects of this levelling process within the sections, these associations are responsible for limiting overall industrial effectiveness by pursuing policies designed to achieve sectional advantage. Whatever the effects of these organisations in their other spheres of influence, it can be said with some certainty that they tend to inhibit technical progress. In this respect the textile industry is no worse than the rest of British industry, in which there are some 2,000 trade associations all operating along more or less similar lines.

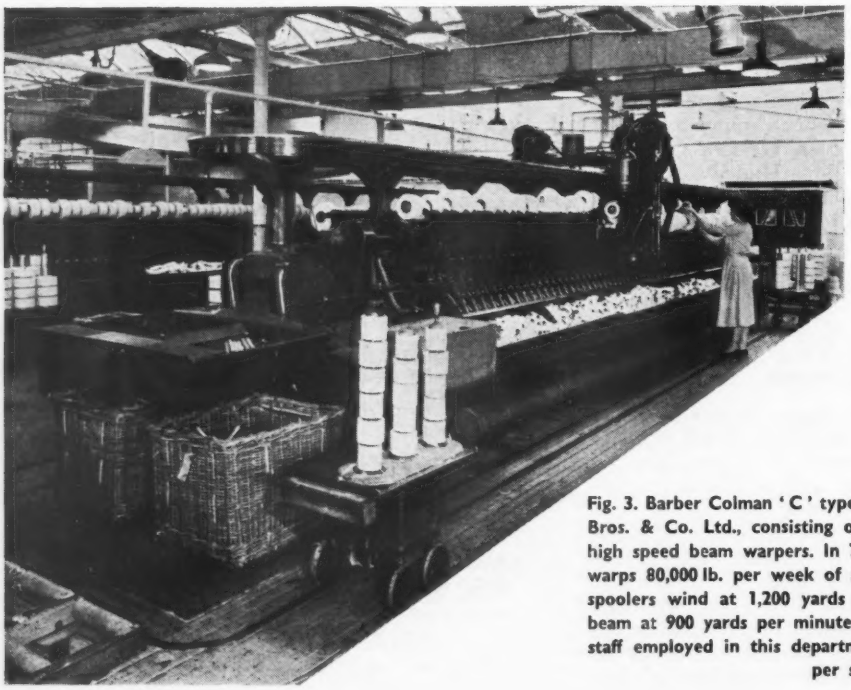

Fig. 3. Barber Colman 'C' type spooler installation at Ashton Bros. & Co. Ltd., consisting of 324 spooler drums and two high speed beam warpers. In 75 hours this plant spools and warps 80,000 lb. per week of an average count of 14's. The spoolers wind at 1,200 yards per minute, and the warpers beam at 900 yards per minute. The total direct and indirect staff employed in this department consists of 16 operatives per shift.

In general, trades unions have been less reactionary in the textile industry than in some of the metal-working industries. In the manufacturing section the numerous unions have, in the main, been both co-operative and helpful. In the spinning section the position is less satisfactory, with marked disparities between different districts, but even here some belated progress is now being made. The full technical exploitation of many capital development schemes in the spinning section has been severely limited by trade union adherence to long-discredited concepts, and it is probably not surprising that in those districts where unions have used their influence restrictively, their members have suffered most in the contraction and reduction of activity which has taken place during the last three years. Forward of the final spinning operation, progress has been impeded by the complexity of union organisation. In our own mills we negotiate with 13 different unions, which makes co-ordination needlessly difficult. Some reorganisation of union structure in the manufacturing sections is long overdue.

a spectacular influence

Probably the most spectacular influence on both production and productivity has been the duty-free importations of cloth from India and Hong Kong. No high wage economy can possibly deal effectively with competition from low wage economies in the manufacture of a commodity in which the labour content per unit of output is relatively high. The most efficient spinning and weaving unit, using the most advanced equipment currently available, could not neutralise the four-fold disparity in wages, after making capital recovery charges. It is an interesting speculation that by installing technically advanced equipment, these countries would lose almost the whole of the price advantage which they now have! There has been much captious criticism regarding the trade's reaction to these imports, generally from industries which are protected by high import duties. The United Kingdom textile industry buys all its capital equipment, dyestuffs and chemicals, synthetic yarns, fuel and services in a protected market, and is compelled to sell its products in a predominantly free-trade market. Some of the most technically advanced textile machinery is of Swiss, German and American origin, and the industry is frequently obliged to make the choice between a technically inferior United Kingdom built machine, or pay 20% import duty.

It is clearly national policy to maintain engineering and other exports at the expense of the domestic textile industry, but the Government could use fiscal and other measures to cushion the full impact of this policy until appropriate readjustments have been made. The most difficult military operation to organise and carry out is the organised withdrawal, and the same can be said of the industrial equivalent. If the contraction proceeds at such a rate that technical and commercial schemes to contain it have no time to develop their full effectiveness, then the resulting attrition may indiscriminately destroy the efficient and the inefficient alike. The process of natural selection cannot be extrapolated without limit!

Finally, some reference should be made to the effect on productivity of the methods by which the industry distributes its products. The aspect of the industry's structure has many technical consequences, which will be discussed in the appropriate section. It should, however, be stated at the outset that the wholesale/retail system is not only expensive in an absolute sense and, generally, adds to the product a cost increment quite disproportionate to the service, but, what is of much more importance, it projects back into the mills excess costs which do not have to be carried by the large number of our European competitors.

The differences in United Kingdom and U.S.A. levels of productivity in textile mills is due to a large number of causes, some economic, some organisational and some technical. Probably the most significant single difference can be accounted for by the more stable manufacturing conditions in the U.S.A., with small set-up costs, special purpose low-flexibility machines, simple production programming and, probably most important of all, concentration of technological and managerial effort on a small range of products. In production engineering, as in so many other spheres of human activity, diffusion of effort leads to failure in detail. This diffusion of effort can be traced to the distribution system failing to carry out its functions of market research, forward purchasing and stock-holding. Every relatively small change in demand is communicated back to the mills with very little damping effect from the distribution system. This leads to over-fragmentation of orders, uneconomic batch sizes, and production schedules analogous to fever charts. The ultimate effect is to cause the manufacturer to supplement his production programme with stock quantities. Thus, resources vitally needed for capital development projects are required for financing the carrying of stocks.

the technical problems

(i) *capital requirements*

Probably the greatest technical difficulty which faces the industry is its shortage of capital. Compared with the remainder of European mills, the industry generally is not equipped to meet normal competition. This excludes a number of excellent firms and units which compare well with the best in Europe, or even the U.S.A., but the modal mill is obsolescent if not obsolete. In the cotton spinning section in 1955, 13.2 million of the 25.9 million spindles in place were mule spindles. In the manufacturing section only 46.000 of the 317,000 looms in place were automatic. Table III shows the relative technical positions of other European industries. Needless to say, in the U.S.A. all spindles are ring and all looms are automatic. It is clear from this that a high proportion of the industry's equipment is "over the hill".

It should not be thought from this that nothing has been done in recent years to ameliorate this

TABLE III
COMPARISON OF BASIC SPINNING AND WEAVING MACHINERY IN WESTERN EUROPEAN COTTON TEXTILE INDUSTRIES, 1956

Country	Spinning spindles (millions)		Looms (thousands)	
	Mule	Ring	Ordinary non-automatic	Automatic
Belgium	—	1·6	24·5	10·1
France	0·2	5·3	64·4	71·7
West Germany ...	—	5·9	77·9	50·2
Italy	—	5·7	41·0	83·5
Netherlands ...	—	1·0	29·0	11·3
U.K.	10·7	13·2	270·3	46·4

Source: International Federation of Cotton & Allied Textile Industries.

situation. For example, between 1948 and 1954, £101,400,000 was expended in the spinning, weaving and finishing sections, and the post-war expenditure up to the end of 1957 is about £165,000,000. Table IV shows the distribution of this expenditure between 1946 and 1957.

This is indicative of much more determined and progressive policies than the industry is given credit for, and compares favourably with the intensity of capital development in other industries. It is worth noting that the numerically smaller sections, spinning and finishing, have been able to direct a higher proportion of their earnings to capital developments than the weaving section. This is hardly surprising in that the horizontal weaver is squeezed between fixed yarn prices and fixed finishing costs, and sells the final product at market prices over which he has no influence. With his own costs as the balancing constituent in the pricing structure, it is hardly surprising that he has been relatively less prosperous by any index of comparision than the spinners and finishers.

What does £165,000,000 represent in relation to the capital requirement of the industry? There is a popular fallacy that the textile industry requires relatively little capital per operative employed in relation to other industries. This probably applied before the First World War, was slowly changing in the inter-war period, and has been invalidated by the post-war technical revolution in processing textile fibres into yarns and yarns into fabrics. In 1954 the cost of erection of new mills was as shown in Table V.

On a single shift basis this corresponds to a *per capita* investment of £6,670, £6,670 and £1,500 in the spinning, weaving and finishing sections respectively. Even if double shift working of all the facilities is possible the figures still compare favourably with *per capita* investments in the newer, glossier, more sophisticated industries. It should be appreciated also, that the above units are equipped for the manufacture of a single simple product.

Table VI shows the concentration of capital in some sections of the mills of a progressive textile

TABLE IV
CAPITAL EXPENDITURE AND EMPLOYMENT

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1946 to 1957
Cotton spinning and doubling (a) ...													
Capital expenditure (£ million) (e) ...	(3·0)	(3·8)	4·7 (f)	5·6 (f)	(5·8)	8·6	6·8	5·4	6·3	7·5	6·9	6·7	71
Average number employed (000's) ...	(133)	(143)	155·0	159·8	162·9	173·5	144·1	154·4	153·4	140·3	132·9	136·8	149·1
Capital expenditure per employee (£'s)	—	—	30	35	—	50	47	35	41	53	52	49	480
Cotton weaving (b)													
Capital expenditure (£ million) (e) ...	(1·8)	(2·8)	3·0 (f)	4·2 (f)	(4·5)	4·4	3·4	3·0	3·5	3·1	4·1	3·1	41
Average number employed (000's) ...	(94)	(99)	104·8	112·1	118·2	118·4	105·3	107·9	105·1	97·9	93·3	91·8	104·0
Capital expenditure per employee (£'s)	—	—	29	37	—	37	32	28	33	32	44	34	390
Rayon, nylon, etc., weaving & silk (c)													
Capital expenditure (£ million) (e) ...	—	—	2·7 (f)	—	—	4·3	—	—	3·2	3·3	3·1	2·9	—
Average number employed (000's) ...	—	—	45·6	—	—	51·9	—	—	53·0	51·4	49·2	50·9	—
Capital expenditure per employee (£'s)	—	—	59	—	—	83	—	—	60	64	63	57	—
Textile finishing (d)													
Capital expenditure (£ million) (e) ...	(1·1)	(1·6)	2·8 (f)	3·7 (f)	(4·3)	5·4	5·0	5·3	5·9	6·7	5·7	5·6	53
Average number employed (000's) ...	(67)	(76)	80·2	84·7	87·9	39·5	85·7	85·9	86·3	82·8	82·8	81·8	82·6
Capital expenditure per employee (£'s)	—	—	35	44	—	60	58	62	68	81	69	68	640

Source: Census of Production. Figures in brackets are rough estimates derived from other sources.
(a) Includes the spinning of staple fibre on cotton spinning machinery and the manufacture of cotton sewing thread.
(b) Includes the manufacture of surgical dressings, etc.
(c) Includes the throwing and spinning of silk, the doubling of man-made fibre yarn and the manufacture of silk and man-made fibre sewing thread.
(d) Covers the finishing of all textile yarns and fabrics.
(e) Covers the acquisition of new and second-hand plant, machinery and vehicles and new building work.
(f) Excluding capital expenditure on new establishments which had not started production during the year.

TABLE V
COST OF ERECTION OF MILLS, 1954

Section	Product	Output (45 hrs.)	Equipment	Operatives	Cost of machinery	Cost of buildings
Spinning ...	36's counts	36,000 lb.	50,000 rings	180	£600,000	£600,000
Weaving	70 x 70, 36/36	180,000 yds.	1,000 x 40" automatic looms	150	£700,000	£300,000
Dyeing	Medium weight	250,000 yds.	—	160	£160,000	£80,000

Source: The Cotton Trade in Britain—Robson.

company. The £165,000,000 expended on capital investment since the War represents an investment of about £650 per head of the industry's present labour force, compared with the £5,000 necessary for technical parity with our competitors. It is clear from this comparison that a much higher rate of capital development is essential if workers in the industry are to be provided with the equipment which they deserve, and without which their holds on their jobs can only be regarded as tenuous in the extreme.

This applies particularly to the manufacturing section. Although the spinning section still operates more mule spindles than ring spindles, considerable progress has been made, and the industry's yarn requirements could be met if all ring spindles were organised on a multi-shift basis. The manufacturing section, however, still operates four non-automatic looms for every automatic loom, and as a large majority of the latter are already running on a multi-shift basis, there is little opportunity for mitigating this position by scrapping obsolete plant and running the remainder at a higher level of activity. This demonstrates the great danger of sectional thinking. Only a small proportion of yarn spun is saleable as thread. The remainder is the raw material for fabric production, and if the processes of fabric production are inefficient, fabric business will be lost and spinners and finishers will find that sectional efficiency is no insurance against such a situation.

(ii) *organisation of facilities*

For many years there has been much controversy as to the extent to which technical progress is being impeded, and the industry debilitated, by its basically horizontal structure; spinning, weaving and finishing units being largely independent of each other. At the present time a great deal of regrouping is taking place within the industry. In some instances this consists of integration forward by the spinner acquiring manufacturing and converting facilities. The backward integration, where converters acquired manufacturing facilities, and which was a feature of the immediate post-war period, appears to have ceased. Indeed many of these manufacturing units have now been closed or otherwise disposed of. Some spinners have also pursued a policy of aggregation as distinct from integration. This applies particularly to

TABLE VI
Concentration of capital in certain textile operations

Brief description of machinery	Units assigned per operative			*Investment/machine (£'s)	Investment/head	
	Direct	Ancillary	Total		Single shift	Double shift
Sulzer shuttleless weaving installation, TW11/130" machines	20	13·3	8	3,500	28,000	14,000
Barber Colman 26 spindle flat steel heald drawing machine	1·0	0·5	0·33	20,000 (plus £20,000 on healds to feed m/c)	13,330	6,665
Schlafhorst Continofil high speed filament weft winder (machine of 11 spindles) ...	3·0	—	3·0	2,000	6,000	3,000
Platts MR3 twist spinning frames with S.K.F. drafting	4	5·1	2·2	3,850	8,450	4,225
Tatham 3 roller and clearer waste cards ...	12	12	6	1,150	6,900	3,450
Northrop RS automatic single shuttle filament looms	30	17	9·2	700	6,400	3,200

* Machine only, excluding proportion of buildings and services.

TABLE VII
TYPE OF UNITS WHICH HAVE CEASED PRODUCTION SINCE JANUARY, 1955

Type of activity	Spinning	Doubling	Weaving	Finishing
Spinning only	40	—	—	—
Doubling only	—	38	—	—
Waste spinning only	3	—	—	—
Spinning/doubling	16	16	—	—
Waste spinning/doubling	1	1	—	—
Weaving only	—	—	249	—
Spinning/weaving	4	—	4	—
Waste spinning/weaving	3	—	3	—
Doubling/weaving	—	4	4	—
Spinning/doubling/weaving	4	4	4	—
Finishing	—	—	—	30
TOTAL ...	71	63	264	30

Note: 1. Where a combined mill has ceased one main group of operations it is included in the table.
2. Average size of spinning unit closed=58,000 mule equivalent spindles.
,, ,, doubling unit closed=9,000 spindles.
,, ,, weaving unit closed=266 looms.
3. Of the 264 weaving units, 109 were also converters, while a further 62 formed parts of groups or combines which include converting among their activities.
Source: The Cotton Board Statistical Department.

the larger spinning combines who are acquiring ring spinning facilities to replace the mule mills which are gradually being taken out of production. There has been relatively little integration between manufacturing and finishing, and very few manufacturing units possess finishing capacity.

If organisation is as decisive as it is supposed to be, it should be profitable to examine the structure of the units which have capitulated to competition during the past four years. Table VII shows the distribution of the 392 units which have ceased production since January 1955. It is evident that the horizontal weaving unit has fared far worse than the horizontal spinning unit, or the combined or fully integrated mill. It is also clear that access to distribution facilities has not proved so advantageous for the weaver as might have been expected. Of the 264 weaving units to close down, 109 were owned by converters, whilst a further 62 formed parts of groups or combines which included converting amongst their activities. Spinner/weavers have contracted much less than either the horizontal spinner or weaver. In March 1956, combined spinner/weavers controlled 113,000, or about 33% of the industry's looms, and this number has tended to remain relatively constant during the period which has seen the closure of 249 horizontal weaving units, and 60 horizontal spinning or doubling units. It should be pointed out that most of the horizontal spinning and doubling units went out of business for technical rather than commercial reasons. The doubling units contracted as a result of the change to cheap single yarn poplins. The spinning units — which were mainly fine-count mills — were generally balanced at higher counts than the current trade demand, and were uneconomic in relation to ring spinning mills.

These results cannot be explained exclusively by differences in organisation. For example, it is strongly suspected that whilst the horizontal weaving firm is indefensible on technical grounds, the rapid contraction of this large section of the industry has been accelerated by the price-fixing arrangements in the other two sections. Similarly, the relative stability of the spinner/weaver group can be partially explained by the protection offered by minimum yarn price agreements. So far, survival has been the only criterion considered. What of profitability? It has already been indicated that horizontal spinners and finishers have been relatively more profitable than weavers — and probably spinners/weavers. Why then have spinner/weavers not been as successful from a profitability as from a survival point of view? Much of the so-called integration which has taken place between spinners and weavers has not been integration in the technical sense. The acquiring of manufacturing facilities by a spinner — or *vice versa* — does not necessarily result in integration. Generally the spinner has been satisfied if his newly acquired weaving units produced a steady requirement for yarn at fixed prices, or the weaver has been satisfied if his spinning facilities enabled him to obtain a yarn margin on his cloth production. These advantages may well prove to be illusory.

The real economies can only be realised by such technical measures as installing spinning equipment to produce the optimum ring package for weaving preparation; installing high-speed preparation machinery which requires a high degree of rationalisation and stability of both the spinning and weaving processes which it links; purchasing cotton to spin yarns for specific known end uses instead of a multiplicity of unknown end uses; and obtaining complete control of the development of new products

and the quality of the finished product at every stage in manufacture. This artificial break between the two groups of processes generically described as "spinning" and "weaving" produces very great technical impediments. For example, the painfully slow introduction of the automatic loom can be directly related to it. Whilst automatic looms represented only 15% of total looms installed in 1957, 67% of these were operating in combined mills. As combined mills controlled only 33% of the looms, it follows that the concentration of automatics is some four to five times as great in combined mills as in horizontal weaving mills. It is absolutely essential for successful operation of these machines that all stages of warp and weft preparation are under the control of the weaver. As the most effective warp preparation machinery can only operate successfully from ring twist packages made to special requirements, it follows that control of ring spinning machinery and, *per se,* all spinning processing, must be under the control of the automatic loom weaver. Further, for certain types of products, direct spinning of weft for the automatic loom shuttle still produces an economy which cannot be fully absorbed by even the most highly productive automatic winding sequence. This argument also operates in reverse. A spinner cannot install high speed preparation equipment if the horizontal weaver he supplies cannot process yarn from the high capacity containers which are characteristic of such equipment. How many horizontal weavers in Lancashire are capable of processing yarn from Barber Colman super-speed warping on their sizing equipment or high-speed spools in their warping equipment? Similar limitations are imposed on selection of spinning equipment. High capacity equipment is always relatively inflexible, and so long as a spinner is required to satisfy a heterogeneous demand, his machinery must have some built-in flexibility which can only be achieved at the expense of machine-productivity. Such developments as S.G. spinning in association with 'D' or 'DD' type Barber Colman spooling is only a practical proposition for mills so organised that all the processes from bale breaker to cloth inspection are regarded as stages in fabric production — as distinct from constituent parts of a trisected industry.

(iii) *diversity of output*

There is no doubt that the Lancashire textile industry is more highly diversified than any other, either in Europe, Asia or U.S.A. This is partly the result of the industry's organisation. The horizontal organisation lends itself to manufacturing diversity. There is no requirement for quantitative and qualitative balance between the spinning, weaving and finishing operations, which is essential for economic operation in a vertical mill. In the great majority of cases, manufacturing capacity is moulded to an aggregate of variegated orders which the selling function have accumulated, and only in a very small number of cases is a production programme fixed and the sales staff organised to sell the resulting output. If we define these two extremes as the "sales-positive" and the "sales-negative" cases, the Lancashire industry is very largely "sales-positive", with

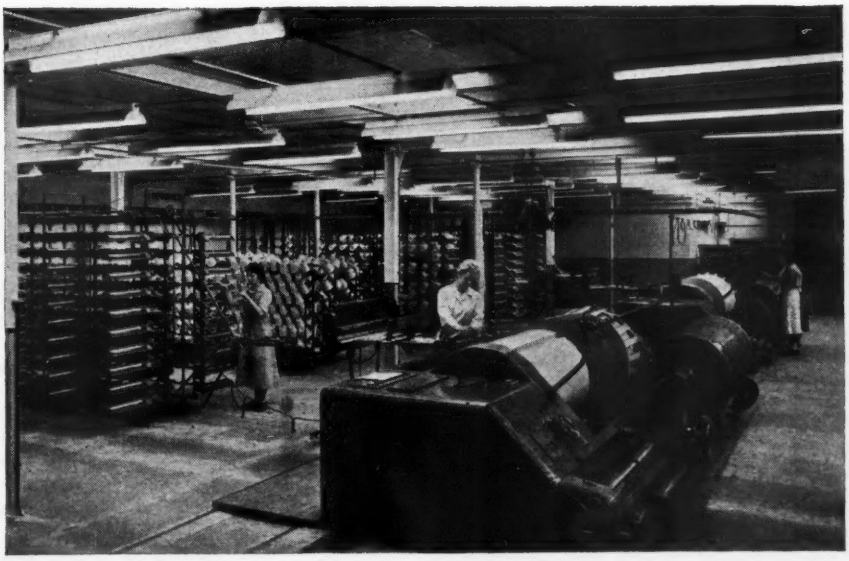

Fig. 4. Benninger high speed section warper installation at Ashton Bros. & Co. Ltd. Developed principally for the beaming of filament yarns for beam to beam sizing, these machines have been adapted for the production of fine count single and two fold cotton warps direct from package dyed cones. Techniques have been developed for winding the yarns preparatory to pressure dyeing, dyeing and subsequent beaming off, which collectively obviate the necessity for a rewind operation after dyeing. 50's single and 2/100's yarns are processed in this way for short-run, high quality coloured woven goods. The end and end leases applied at the machine can be carried through warp sizing so that the warp can be presented to the Barber Colman automatic warp drawing machine.

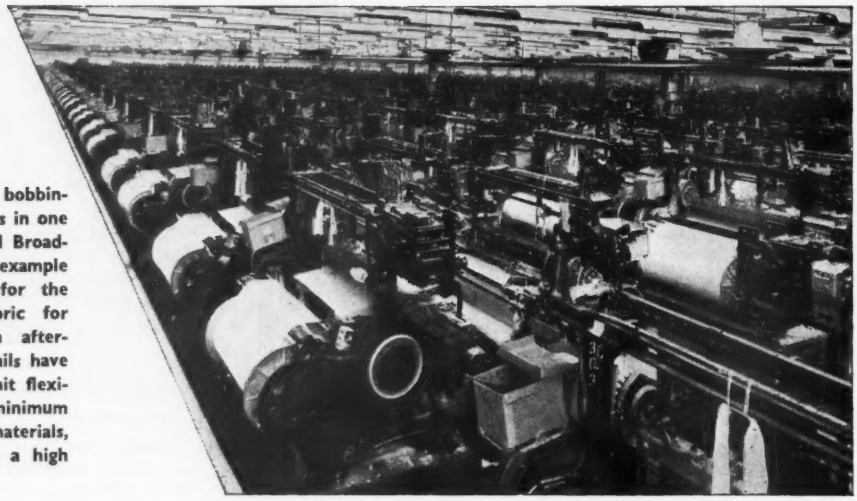

Fig. 5. Northrop automatic bobbin-change dobby and tappet looms in one of the weaving mills of Tootal Broadhurst Lee Co. Ltd. This is an example of a bulk production unit for the weaving of standardised fabric for subsequent embellishment in after-processing. The structural details have clearly been designed to permit flexibility in loom layout and minimum interference in the moving of materials, which in a textile mill have a high bulk/wt. ratio.

a few units whose motivation could be described as "sales-neutral". In general, the horizontal weaver is organised on a jobbing or small batch basis, and the horizontal spinner aggregates the yarn requirements of a large number of weavers. The characteristics of the horizontal spinners' production depend on the weavers' highly diversified requirements, and some under-employment of resources is almost inevitable. In very few industries is process balance so important as in cotton spinning.

The combined spinning and weaving mills with converting resources do not, generally, exhibit the greater degree of stability which might be expected. This is, to some extent, due to the fact that they are frequently appendages and not integral parts of a single unit. They take in each other's washing; they are not highly co-ordinated jointly to produce and sell an annual production of specified standardised products. Another reason for the production facilities being subjected to this pressure is that their equipment makes it possible! The European and U.S.A. industries are obliged to run their affairs more intelligently because their fully-automatic, high-capacity equipment is incompatible with this pantagraph relationship between the commercial and production functions. Furthermore, the balance between spinning, weaving and finishing

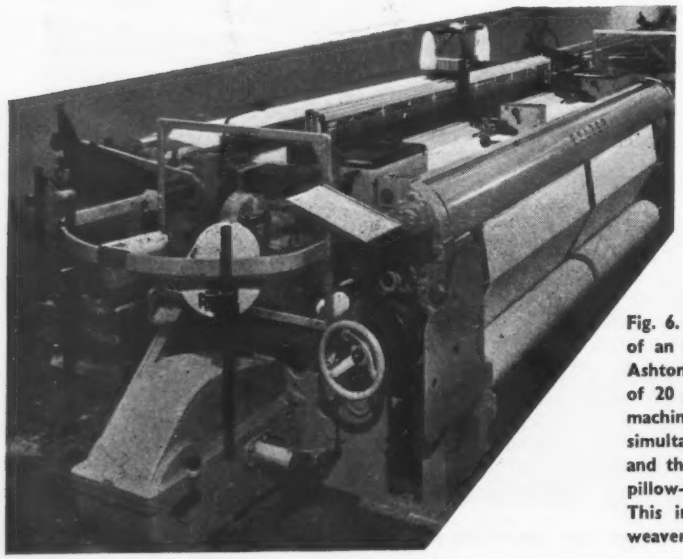

Fig. 6. Sulzer shuttleless weaving machine TW11/85 in., part of an installation of 85 in. and 130 in. weaving machines at Ashton Bros. & Co. Ltd. This particular loom is one of a set of 20 per weaver, 16 × 130 in. and 4 × 85 in. The 85 in. machines are weaving two high-reed two-fold poplins simultaneously. The machines are running 24 hours per day and the set is producing 70 pieces of sheeting, 70 pieces of pillow-cotton and 46 pieces of two-fold poplin per week. This installation is now being built up to a unit of two weavers sets to weave 14,000 lb. wt. of fabric per week.

Fig. 7. General view of Sulzer shuttleless weaving machine installation at Ashton Bros. & Co. Ltd., taken at the stage when 20 machines were in operation.

imposes very considerable restrictions on what can or can not be made. Only a relatively narrow range of products can have a processing balance in these three groups of processes. Any deviation from this narrow range would either stop the finishing mill or overrun the spinning operation. It is for this reason that one finds so many "single-product mills" in the U.S.A. and Europe. These are mostly completely vertical and highly specialised. One finds gingham mills, poplin mills, sheeting mills, tyre mills, rainwear mills, towel mills etc., each making a narrow range of varieties of a single product. In Lancashire it is not unknown for a heterogeneous collection of products to be manufactured in one mill, the scale of activity on each product being such that economic operation is quite impossible. This diversity also precludes of any vertical development as the scale of activity is much too small to support either yarn spinning or finishing. It would be quite impossible, for example, to integrate finishing sheeting in the most modest continuous installation unless the production of about 500/600 double shift looms was available to support it. Similarly, to support spinning facilities a poplin mill would have to run at least 800/1,000 double shift looms on a relatively narrow range of yarn counts and cloth qualities.

It follows that there is a fundamental difference in approach towards textile manufacture in the United Kingdom to that most frequently found in mills abroad. In Lancashire, technical effort is spread over a wide group of products through a short series of processes. Our foreign competitors apply their technical effort to a narrow range of products through a much longer series of processes. This latter arrangement permits the use of special-purpose, high-capacity equipment, improved control over quality of the finished product and generally simplified administrative procedures. The multi-product manufacturer, operating below the economic scale of activity on every one of his products, and purchasing a proportion of his yarns and finishing services, couldn't possibly live in competition with such specialised vertical operation. Many manufacturers responded to the Asian competition of the 20's and 30's by diversifying their range of products up to the limit of the infinitely flexible Lancashire dobby box loom, and the skill of the Lancashire textile operative. Once established, this high degree of diversification became a very great inhibitor to technical progress, and what was a short-term lifeline could be a long-term millstone. All the evidence suggests that the cost of this high diversity through a short series of processes is high production costs today, and technical inferiority tomorrow. This grouping of production facilities to permit of through-manufacture on an economic scale must be the king-post in any new organisational structure. There is little evidence to suggest, however, that the regrouping at present taking place within the industry is being motivated by technical economy factors.

the shortage of managerial and technical personnel

In the previous sections I have outlined some of the industry's major problems. Production engineers will readily appreciate that some solution will have to be forthcoming if there is to be any spectacular transition from labour-intensive to machine-intensive methods. The industry has clearly to contract numerically in both machines and units, and there is no substitute for competition if this process is to be carried through at the requisite speed and without debilitating the serious contenders for survival. Fundamental changes in organisation are necessary, and three process groups must intensify their capital development schemes, running the new equipment on a two- and three-shift basis. It is difficult to see how this can be achieved without some external assistance for capital development. This applies particularly to the manufacturing section. Table VIII shows the changes necessary in loom equipment to produce the 1957 volume of output in the same distribution of

TABLE VIII

	Installed capacity and current method of operation. 1957	Reorganised capacity and method of operation
Non-automatic looms:		
single shift	265,000	54,000
double shift	—	—
treble shift	—	—
Automatic looms:		
single shift	9,500	—
double shift	29,000	113,000
treble shift	—	—
Shuttleless looms:		
single shift	—	—
double shift	—	—
treble shift	—	7,000
Total weaving units in production for similar output in quality and diversity ...	303,000	176,000

Source: Warp Preparation and Weaving—Ormerod. National Federation of Textile Works Managers, Annual Conference Proceedings, 1957.

qualities and products. These changes would have to be supported by comparable changes in preparation and ancillary equipment, and it is estimated that an expenditure of £83 million would be necessary to purchase the equipment required. How does this £83 million relate to the resources available to meet it? The manufacturing section has expended £41 million on re-equipment during the past 12 years — of which eight were unusually profitable. The net output from the manufacturing section in 1948 was £48.5 million 1. Reliable data on profits is not easy to obtain, but the section's annual profit is likely to be less than £3 million. All the evidence available indicates that the necessary finance is well beyond the industry's own resources.

It is also beyond the industry's present technical man-power resources. Some of the installations shown in the photographs in this Paper are quite outstanding in technical merit — by any standards — and they demonstrate quite clearly that when the best technical management has access to adequate capital, the Lancashire textile operative can achieve technical performances which cannot be achieved in any other textile producing country in the world. Indeed, some of the advanced techniques in use in a few mills in Lancashire are quite unique. A few of these are very briefly summarised in the captions to the photographs. Unfortunately, these are by no means typical of the industry as a whole. The number of professionally qualified managers, engineers and technologists is far too small to implement the programme outlined for resuscitation of the industry. Furthermore, as vertical groupings are desirable, management and technical personnel with knowledge and experience of all three sections will be essential to integrate and co-ordinate the re-equipment and subsequently organise and control it. In an industry with horizontal traditions, such men are relatively rare.

In a contracting industry the intake of graduates and chartered technologists tends to be inversely related to the potential for use of their services. Table IX shows the output of trained technical personnel in 1957/8. As a proportion of these will not take up employment in the Lancashire textile industry, it will be apparent that this is grossly inadequate to maintain technical momentum in an industry which still employs almost a quarter of a

TABLE IX
Annual output of trained technical personnel in the industry (all Nationals). Session 1957/58.

Technical graduates	12
F.T.I.'s	5
A.T.I.'s	49
Associates of Technical Colleges (Manchester & Salford) ...	18
Higher National Certificates	28
City & Guilds of London—Finals	90

Source: Cotton Board.

million operatives in mechanical and technical processing.

It would be incorrect to assume that nothing is being done to ameliorate this situation. The Cotton Board Productivity Centre has done a quite outstanding job in introducing modern techniques of management to a large number of organisations. Table X gives some indication of the scope of the work carried out and the degree of penetration which has been achieved. Greater advantage could and should be taken of these excellent facilities. About 75% of the organisations have not supported a single course and few have supported them all. In my own company we use these courses as integral parts of our own training programmes and we are more than satisfied with the results. I have had the opportunity of seeing the work of similar organisations in other industries but none does a better job, generally with considerably greater resources at their disposal. The influence of the Productivity Centre's work, however, cannot be measured by statistics or by the penetration of techniques. They have done much to encourage a critical approach to management problems, and a change in the attitude of mind of those responsible for making decisions.

On the technical processing side, the industry has at its disposal the services of the British Cotton Industry Research Association—the largest corporate research association in the world. The Lancashire textile industry has access to research papers on mechanical processing of fibres and fabrics which are not available to any other textile industry. Unfortunately, the industry's capacity for interpreting and applying the results of research is far below the Association's capacity for producing them. A large number of textile organisations have no professionally qualified member of their staff capable of capitalising on the results of researches to which they subscribe. On the other hand, if one visits textile factories in Germany, Holland, Belgium, France or U.S.A., B.C.I.R.A. publications can almost invariably be found on the plant manager's or departmental manager's desk! It is unfortunate that much of the short-term work of the Association has to be related to the problems of an industry with a high proportion of obsolescent or obsolete equipment, and this results in first-class technical resources being used to deal with problems which do not occur on modern equipment. This prevents a high proportion of the Association's staff and equipment being assigned to work of a more fundamental nature.

TABLE X
Cotton Board Productivity Centre: Record of Courses and Attendance at 15th December, 1958.

Type of course	First Started	Duration	Cost per Trainee	No. of courses held to date	Total No. Trainees On courses to date	Remarks
WORK STUDY OFFICERS	March, 1949	8 weeks	135 gns.	26	226	Full time.
WORK STUDY OFFICER'S ASSISTANTS...	Nov., 1953	6 days	20 gns.	7	66	2 days weekly.
WORK STUDY APPRECIATION						
(a) at mill level	March, 1953	1 week	10 gns. per course	33	341	½ days.
(b) for textile teachers in technical colleges	July, 1953	3 weeks	—	2	20	Full time.
(c) for officers and employers' associations and trade unions	April, 1951	50 days	—	4	48	2 days weekly.
(d) for foremen*	Oct., 1951	6 days	3 gns.	6	152	1 day weekly.
MOTION TIME STUDY* ... ... i.e., M.T.M. and B.M.T.	April, 1954	16 days	21 gns.	3	27	2 days weekly for 8 weeks.
FOREMANSHIP*						
A. Residential						
(i) for the spinning and weaving sections	Oct., 1952	3 weeks	35 gns.	17	228	Cost includes accommodation and meals.
(ii) for the finishing section	Oct., 1953	2 weeks	15 gns.	4	46	Cost includes accommodation and meals.
B. Non-residential						
(i) in districts	Oct., 1954	4 days	5 gns.	7	121	2 days weekly for 2 weeks.
(ii) at Fielden House	Jan., 1956	3 weeks	25 gns.	3	23	
SPECIALISED OPERATIVE TRAINING* ...	Sept., 1955	3 weeks	50 gns.	6	33	
MANAGEMENT ACCOUNTING	Jan., 1956	4 days	20 gns.	15	148	
QUALITY CONTROL	May, 1956	9 days	25 gns.	9	83	
MANAGEMENT CONTROLS*	Sept., 1957	4 days	5 gns.	1	9	
TOP MANAGEMENT						
A. Forums	March, 1954	3 days	2 gns.	5	92	Held at suitable hotels.
B. Briefing Meetings	Sept., 1954	½ day fortnightly	2 gns. meeting	3 seasons	450	At suitable premises through autumn & winter.
WORK SIMPLIFICATION IN THE OFFICE	Nov., 1958	4 days	12 gns.	1	24	

* These items are at present suspended.

Fig. 8. Northrop automatic bobbin - change looms, fitted with Lacey over-motions, in one of the weaving mills of Clegg & Orr Ltd. The pillarless shed construction and high level enclosure of shed services provides excellent weaving conditions — particularly for multi-shift operation on relatively coarse cotton goods.

technical college facilities

The technical college facilities available for the training of management trainees and trade technicians are, in my opinion, inadequate to deal with the revolution in manufacturing techniques with which the trade is now faced. As Sir Willis Jackson [2], Director of Research and Education, Metropolitan-Vickers Electrical Co. Ltd., recently observed: "It is by no means uncommon for senior representatives of industry to be critical of what is taught in technical colleges and, indeed, this is a very desirable state of affairs provided always that these representatives are fully acquainted with the facilities and courses available, and that they are willing to play their established part in a real partnership between industry and education". This imposes responsibilities which the industry must be prepared to accept. It is inevitable in a period of rapid technological change where units of plant are becoming considerably more complex and expensive, that those in industry with the knowledge and experience of practical operation should make their knowledge available to students. The progressive element of any industry must always be ahead of technical college instruction, but this lag could be very markedly reduced if more of those who have the knowledge and experience were prepared

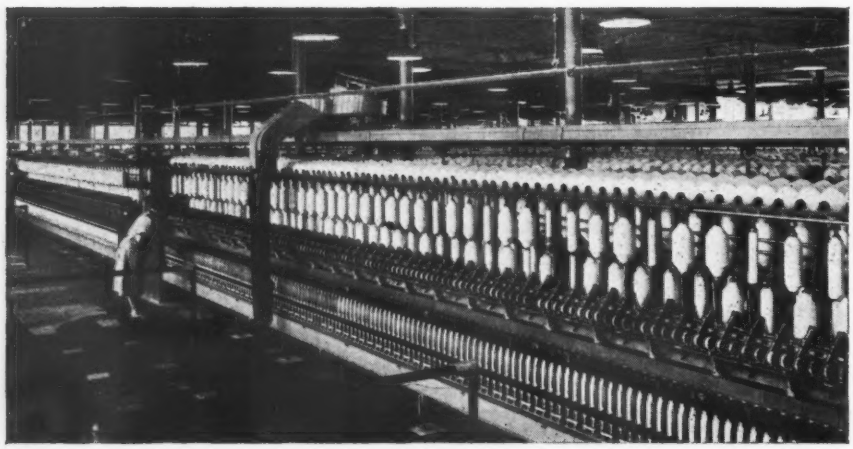

Fig. 9. Installation of Platts M.R.3 ring frames fitted with S.K.F. (P.K.11) drafting equipment and Parks Cramer automatic cleaning equipment at Ashton Bros. & Co. Ltd. These frames are operating 24 hours per day on 9 in. lift, 2 in. ring packages for subsequent preparation in Barber Colman high speed spooling and warping equipment.

Fig. 10. Condenser carding installation in the Cheadle Heath mill of Fine Spinners & Doublers Ltd. Tathams three-roller and clearer cards with ring doffers and condensing equipment and 96-end Derby doublers can be seen in the foreground. An efficient chain conveyor working between the carding and spinning departments can be seen in the background. The opening department, fitted with fully automatic fibre blending equipment, provides laps for the card-room.

to pass it on. Periodic lectures to night-school students is not enough, As part-time day lecturers they would become more closely identified with the full-time lecturing staff, and with the corporate life of the colleges. Both industry and the colleges couldn't fail to benefit by such contact. If we believe with Bacon that every man is permanently indebted to his profession, we should be prepared to do more.

The Institution of Production Engineers can assist materially in improving the standards of management practice in this industry. A substantial proportion of the Associate Membership course content relates to the engineering of production — any kind of production. Under the Institution's "broadening the base" policy, it is now possible for technicians in other industries to submit their own qualifications in mechanical processing as exemption from the engineering and metal-cutting sections of the I.Prod.E. syllabus. The production problems associated with rapid technical and organisational change are the legitimate fields of the production engineer. The Productivity Centre of the Cotton Board has made some progress in adding some of the more advanced management techniques to the mill manager's repertoire, but the management trainee — tomorrow's manager — should have access to formal courses in which he can integrate his industry's process technology with a fundamental knowledge of the principles of production engineering. The industry has then to ensure that such men rise relatively quickly to positions which enable them to influence its affairs. Although there is, unfortunately, no statistical evidence either to confirm or refute this view, it would seem that a relatively small proportion of production men occupy the positions of greatest influence in the industry. It is certainly true that few professionally trained and qualified managers have penetrated to such positions. It may well be that this has a cogent influence on the post-War ratio of change in productivity shown in Figs. 1 and 2. It is a matter of common observation that young professionally trained managers are much more common in Continental than in the United Kingdom textile mills. At the recent Cotton Board Conference, Mr. W. T. Winterbottom — Chairman, Fine Spinners and Doublers Ltd. — admirably summed up the alternatives before the trade as "get on or get out". The rate at which we "get on" is likely to be conditioned by the enterprise, energy, enthusiasm and technical competence which we can bring to bear on our problems. These qualities are not necessarily associated with "a lifetime's experience in the trade"!

conclusions

It is not intended to distil the contents of this Paper into some formal recommendations — a sort of poor man's "Plan for Cotton". The problems of the cotton textile industry are too manifold and complex to permit of the neat, slick solution. Furthermore, not all the views expressed here will meet with

Fig. 11. Platts false-twister condenser ring spinning frames in the same installation as Fig. 10. These machines replace condenser mules for a large number of applications and produce a yarn package admirably suited for subsequent preparation processes and the minimising of knots in fabrics using these yarns.

universal approbation, even amongst those responsible for the production function. Opposing views could probably be argued with equal cogency. It is also appreciated that, regardless of the objectivity of our approach to a problem, it is impossible to eliminate completely the effects of our personal background and experience. Nevertheless, the production viewpoint should be presented. As managers and production engineers we are inclined to become absorbed in details of operation and leave the general direction of our affairs to economists, accountants and politicians. If we take this detached view, we have no justifiable grumble if we are subsequently left to unscramble the resulting muddle.

The Government re-equipment subsidy was a typical example. To qualify for the subsidy a

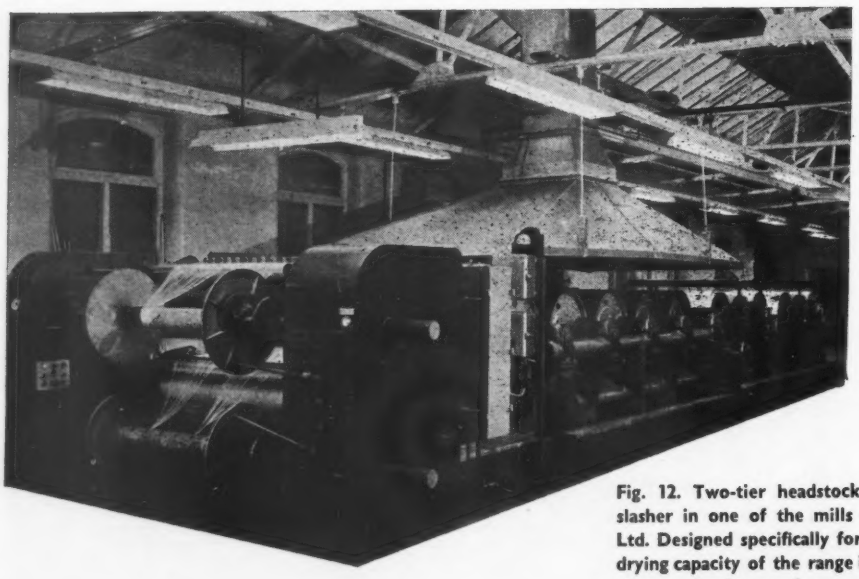

Fig. 12. Two-tier headstock end of Holts multi-cylinder slasher in one of the mills of Smith & Nephew Textiles Ltd. Designed specifically for sizing low density warps, the drying capacity of the range is utilised by sizing two sheets of yarn simultaneously at speeds well above the speed of the normal friction-driven sizing machine headstock.

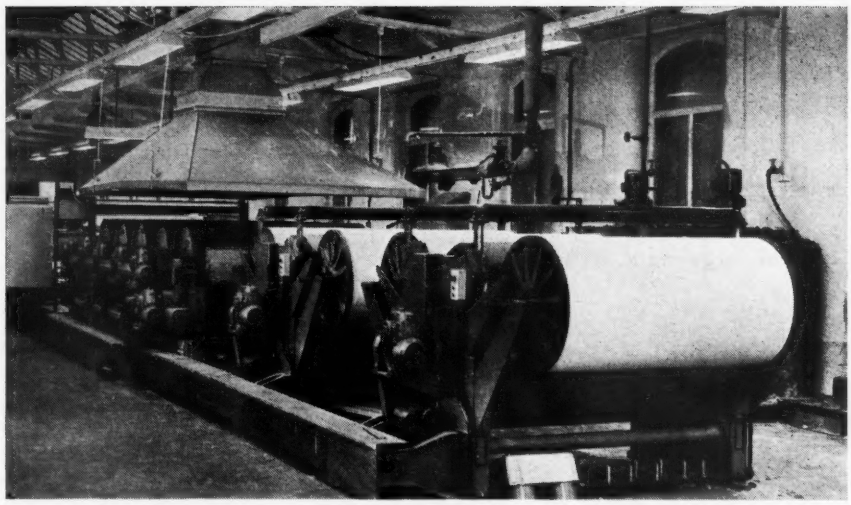

Fig. 13. Rear view of the machine shown in Fig. 12. The high running speeds preclude the normal negative control of the large capacity back beams. These are negatively driven by surface contact with large diameter driving drums and synchronisation between feed and delivery is controlled through infinitely variable gears.

company was required to operate a specified minimum spindleage. No credit was given for preparation, weaving or finishing equipment, although the capital tied up in these sections was greater than in spinning. This clearly encouraged the horizontal spinners to aggregate spinning capacity until they owned the minimum qualification. Although it was obvious that a transition to fully integrated units, equipped and balanced to produce and sell particular products, was required, a direct incentive was provided by the Government to propagate further the already predominantly horizontal structure. Government assistance is now vital if the country is to have a cotton textile industry capable of economically satisfying its requirements, and some response now appears likely. When the form which this assistance is going to take is being decided, it is hoped that technical considerations will not be subordinated to those of a financial and commercial character. The industry can only be resuscitated by a technical revolution. The industry possesses technical knowledge not possessed by any of our competitors, although this is admittedly somewhat thinly and unevenly spread through the industry. We must see that these resources are used, and that those responsible for directing our affairs are made aware that the problem to which they are obliged to find a solution *has a technical content.*

In 1953, The Institution of Production Engineers published a series of leading articles, reprinted from the Institution's Journal, under the general title: "An Expansionist Policy for Production" [3]. In the final article of the series Mr. Lincoln Gordon, Chief of the United States Mutual Security Agency Mission to the United Kingdom, wrote:

"There is no doubt about the progressive firms, large and small, that have kept pace with the best in the country. But no nation can live on the prestige of the few. It is the general average which determines a nation's fate. Is the vast bulk of industry in this country prepared to do all that it must for its own, and the nation's, future security? . . . With respect to self-preservation, Britain as a whole is under extreme pressure to expand its production and increase its efficiency so that it can compete in product, price and delivery on the world market. But so far, in many industries, individual firms have been insulated from the pressure. It would seem that the sooner that pressure could be brought to bear on each firm in Britain, the sooner might all the necessary steps be taken to improve efficiency and production and the sooner might the pressure be relieved from the nation as a whole."

It would now appear that our particular industry is likely to be one of the first to sample this unpalatable remedy. I believe that whilst this may prove a shock for the system it need not be fatal. Provided the technical managers within the industry are given the necessary equipment and the opportunity to get on with the job, the entire resources of our Research Association are extended to the ultimate, and the Cotton Board Productivity Centre is developed so as to bear some relation to the potential requirement for their services — a compact, reorganised and re-equipped industry could emerge, capable of adding lustre to the reputation which once was Lancashire's.

acknowledgments

The author wishes to express his thanks to the Directors of the following Companies for permission to publish photographs of processes and installations:
Ashton Brothers & Co. Ltd., Hyde;
Tootal, Broadhurst, Lee Co. Ltd., Manchester;
Fine Spinners & Doublers Ltd., Manchester;
Smith & Nephew Textiles Ltd., Colne;
Clegg & Orr Ltd., Manchester.

(REFERENCES AND GLOSSARY APPEAR OVERLEAF)

REFERENCES

1. Source: "Census of Production".

2. "Training in British Industry" by Sir Willis Jackson. *Technical Education,* February, 1959, Vol. 1, No. 1.

3. "The Task of the British Productivity Council" by S. P. Chambers, C.B., C.I.E.

"How Few Production Engineers?" by Sir Walter Puckey, M.I.Prod.E., F.I.I.A.

"Trades Unions and an Expansionist Policy for Production" by Sir Vincent Tewson, C.B.E., M.C.

"An Expansionist Policy for Production" by Allan Ormerod, A.M.C.T., A.M.I.Mech.E., A.M.I.Prod.E.

"Summing Up" by Lincoln Gordon.

GLOSSARY

Card
A machine which reduces entangled and matted fibres to a filmy web by working them between two closely spaced relatively moving surfaces clothed with sharp points.

Card, Roller and Clearer
A type of card mainly used for processing woollen materials and cotton waste.

Count of Yarn
A number indicating the mass per unit length or the length per unit mass of yarn.
(In this Paper all counts are in the cotton count system, which is a length per unit mass system. The count number equals the number of lengths of 840 yards per pound. With this system a finer yarn carries a higher count number.)

Doubling ***(when applied to spun yarn)***
1. The operation of combining two or more single yarns into a two-fold or doubled yarn.
2. The industry which carries out the operation described in 1.

Drafting System
A mechanical means (frequently consisting of pairs of rollers or aprons) for the attenuation of a strand of fibres.

Drawing Machine
A machine for drawing the threads of the warp through the eyes of the heald and the dents of the reed.
(Reeds and healds are a device for separating and controlling the movement of warp yarns during weaving.)

Dyeing
The process of bringing about the persistent modification of the original colour of a material (raw material, yarn, or cloth).

Finishing
All operations following bleaching, dyeing or printing and comprising, for example, blueing, drying, raising and shrinking.

Horizontal Organisation
A combination of a number of mills all engaged on the same operation, e.g., a group of spinning mills.

Lap
A sheet of fibres from the opening machinery which has been wrapped round a core.

Loom
A machine for producing cloth by the interlacing of warp and weft threads.

Loom (Automatic)
A loom on which the shuttles or pirns in the shuttles are changed automatically. Automatic looms generally are also fitted with other motions simplifying the work of the weaver.

Manufacturing
The section of the cotton industry which converts single or doubled yarn into grey (unfinished) cloth.
Most yarns have to go through "preparation processes" before they can be woven on a loom.

Mule
A spinning machine which has an intermittent action. It drafts (draws out) a strand of prepared fibres and twists it to form a yarn and then winds the yarn in the form of a cop. This cycle is repeated several times each minute.

Mule Equivalent Spindles
When comparing the spindleage (spindles installed) of mules and ring frames, one ring frame spindle is ranked as equal to $1\frac{1}{2}$ mule equivalent spindles.

Opening Department
After bales of cotton have been checked they are opened and passed through machinery situated in the Opening and Blowing Rooms of the mill. The last machine in this department produces a lap which is supplied to the cards situated in the Card Room.

Poplin
A plain weave fabric with weft-way ribs and a high number of warp threads.

Preparation Processes
The processes which are used to prepare yarn for weaving on a loom.
The warp preparation processes include winding, warping and sizing.

Ring Frame
A spinning machine which produces yarn continuously until a bobbin has been filled. It drafts (draws out) a strand of prepared fibres, twists it into a yarn and winds the yarn on to the bobbin, the three operations being carried out continuously as the material passes through the machine.

Shuttle
The device in which a small package of weft is stored and which carries the weft across the loom during weaving.

Shuttleless Weaving Machine
A machine for producing cloth by the interlacing of warp and weft. The weft is stored in the form of a large cone or spool at the side of the machine, and carried across the loom with the help of a weft carrier, a rapier, or by pneumatic means.

Sizing
The process of applying a film forming substance in solution or dispersion to a yarn (generally a warp yarn before weaving). The objects are generally to make the yarn smoother and stronger to stand the strain of weaving. Sizing is also sometimes used to add to the yarn fungicides, identification tinting colour, and stiffening and weighting materials.

Slasher
A machine used for the sizing of yarn.

Spindle
1. A slender tapered steel rod upon which the cop of yarn is built up in mule spinning and which carries the bobbin in ring spinning.
2. The number of "spindles" installed is a measure of the size of a mill or of the industry of a country.

Spindle Point
Yarn at spindle point is yarn just as spun. At spindle point the spinning operation has been completed.

Spinning
The process or processes used in the production of a single yarn.

Spinning Industry
The "cotton spinning industry" comprises all processes required to transform the raw cotton received in bale form from the cotton fields into a single yarn.

Twist Spinning Frame
Ring frame used for spinning warp yarn.

Vertical Organisation
A company combining two or more of the main processes, e.g., spinning and weaving or spinning, weaving, and dyeing or bleaching.

Warp
1. A number of threads in long lengths and approximately parallel (which have generally been assembled on a beam) which are intended for doubling, dyeing, sizing, weaving or knitting.
2. Threads which are running lengthwise in a woven fabric.

Warping
The process of assembling a number of threads in long lengths and approximately parallel.

Weaving
The production of cloth by the interlacing of warp and weft threads.

Weaving Industry
See: Manufacturing.

Weaving Machines
See: Loom *and* Shuttleless Weaving Machines.

Weft
1. Threads which are running widthways in a woven fabric.
2. Yarn intended for use as in 1.

Yarn
An assembly of fibres or filaments, either natural or man-made, twisted or laid together to form a continuous strand which can be processed into a textile material.

Yarn (Single)
A single cotton yarn is the strand of twisted fibres which is produced either by the mule or the ring frame.

Yarn (Filament)
A yarn consisting of fibres of indefinite lengths (e.g., silk yarn and extruded man-made fibres which have not been cut into short lengths for staple fibre spinning).

CORRESPONDENCE TO HEAD OFFICE

There have been quite a number of instances where post intended for Head Office has been delayed, due to the fact that the envelopes have not been clearly addressed, and it may also be assumed that, for the same reason, a number of letters do not reach this office at all.

There are quite a number of places in London which include the name "Chesterfield" in their address, for example, Chesterfield Gardens, W.1., Chesterfield Road, W.4, etc. Delivery of correspondence to Headquarters can only be guaranteed if the envelope, or other package, is accurately addressed. The word "Street" must be written in full, as the abbreviation "St.", when in manuscript is frequently — and understandably — read as "Sq." or "Pl.", and is delivered accordingly with consequent delay. In order to help overcome this problem, it is intended in future, to include the word "Mayfair" in the Institution's address.

Any mail being sent to the Institution must be addressed as follows:-

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10 CHESTERFIELD STREET,
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The increased size of the Journal has made impractical the present type of binder, and as a result of requests from members, the Institution is now able to supply the "Easibind" type of binder, in which metal rods and wires hold the issues in place, and which is designed to hold six Journals.

It will be found that copies of the Journal can be quickly and simply inserted into this binder, without damage to the pages, and that binding six issues at a time, instead of twelve, will facilitate easier reference, and handling of the volumes.

The new binders may be obtained from: The Publications Department, 10 Chesterfield Street, Mayfair, London, W.1, price 10/6 each, including postage. Date transfers, for application to the spine of the binder, can be supplied if required, price 6d. each.

A British Viewpoint on International Standards*

by H. A. R. BINNEY, C.B.

Director
British Standards Institution

THE British outlook on international standards reflects our economic and trading position. The United Kingdom participates in almost every committee of the I.S.O. and I.E.C. and holds the secretariat of a larger number than any other country. This is no boast; it is just a measure of our interest in that we export and import an enormous range of goods and materials and that every country in the world is a market or potential market for our goods. We live by export because we have to depend on imports.

Most of us would probably agree that standards, even on the national scale, came too late in the industrialised world to avoid much costly, undesirable, diversity. If that is true at the national level, it is much more true of international standards work. Admittedly, a considerable amount of work in the electrical field has gone on over the past 50 years under the aegis of the International Electrotechnical Commission, largely because safety rules and regulations in the distribution and use of electrical energy almost compelled international thinking on the subject, if international trade in electrical goods and apparatus was to survive and grow. But in all other areas of international trade, really substantial progress has resulted only from the work of the last decade.

One of the first standardisers of international significance was the great Joseph Whitworth, with his standard screw thread system. That was a century ago. People did not pay attention then to the possibility of international standards, as such. There was no International Standards Organisation; if there had been, a single unified world system of screw threads could have been achieved then and there. Instead, we have had to wait a century, until June of 1958, for any form of world agreement. This was at the I.S.O. Conference at Harrogate, when agreement was reached on two systems — the unified inch screw thread system for inch countries and a common metric screw thread system for the metric countries. That, I think, was a real triumph of negotiation. Much benefit will flow from it. Even so, it still leaves two systems, not one, and it still leaves the big problem of the changeover for some countries. And the losses which that undesirable diversity of a century has cost is incalculable.

importance of getting abroad

I mention this to emphasise the fact that the time to effect international agreement on the basic standards practices is early; we can hardly be too early. This also points up the special importance of getting ahead with work in the newer industries like nuclear energy, plastics and electronics, before practices have had time to become set in separate patterns in the different countries. It is reassuring to see the powerful contribution which the U.S.A. is making to the work of the new I.S.O. Technical Committee 85, on nuclear energy; the work which the U.S.A. is doing in ISO/TC 61 on plastics, which held a further meeting this very month in this country; and there is the vast volume of work now going forward on electronics in the I.E.C.

The fact today is that the concept of international standards is here to stay and that, quite suddenly, the

* *A Paper presented to the U.S. National Conference on Standards, in New York, November,* 1958.

scope and pace of developing agreements on international standards have quickened tremendously. Any country, or any particular industry of any country, that holds aloof from this work will do so at its peril.

What should be the characteristics of an international standard? My view is that, just as the national standard often needs to give more choice, more flexibility, than the company standard, so the international standard must frequently be designed to provide a framework within which the different national standards can build up their own more detailed specifications, while complying with the essential features agreed internationally. In the same way as we prefer in the United Kingdom to base our quality standards on performance tests rather than construction specifications, so as to give manufacturers greater freedom of design and methods of production, so we feel that similar and perhaps greater flexibility should frequently be sought in the international standard. Many I.S.O. Committees have very soundly started their work with the drawing up of agreed methods of test, a useful step in itself to ensure fair comparison of different countries' products, and an essential for the specification of qualities suited to different uses.

a flexible attitude

As well as flexibility in the international standard itself, we need flexibility in the attitude of the national delegations to international meetings, and a refusal to cling to national standards merely because they are ours and long established. This is where my own country is sometimes a serious offender. But time and again from those of the highest standing in my country, and out of it, I hear the plea that the national standards we put forward as a basis of international acceptance must be technically sound, and demonstrably up-to-date. We are apt to rest on past laurels, and fail to recognise that our high safety margins, or whatever it may be, can be achieved by more accurate calculation of stresses and better use of modern materials and techniques. We and other delegations have to remember our responsibilities to the industries of the world to reach agreement on a reasonable standard, not to fight for our own and seek to impose it on others.

Where dimensions are concerned the international standard, because of the two systems of measurement in the world, must specially concentrate on functional interchangeability between products or components, whether measured in inch or metric units. Where this is impracticable and two series are established, the dimensions in inch units and those in metric units must have equal status.

The problem of inches and millimetres arises so often that I would like to underline three features :-

(i) The "metric" system is not the "decimal" system. The decimal system is a form of mathematics which we all learn at school and is related solely to numbers; it is equally applicable to all kinds of measures.

(ii) There exist in the world today two primary systems of linear measurement, the inch system and the metric system. Neither in my view is likely to give place to the other within any forseeable period and we should therefore accept that they both exist and possess equal status. If enthusiasts from both schools of thought would accept and work from this basis, instead of prophesying that one half of the world will suddenly abandon one system of measurement in favour of the other, then we should all get along much faster.

(iii) In order to align dimensional standards amongst inch and metric countries, we should approach the problem in the following sequence :-

(a) Is it a case where a single series, expressed in one system of measurement only, will be acceptable in all countries?

(b) Is it a case where a single series will be accepted, derived from one system but expressed in both systems by exact translation? In such cases, the system from which the series was derived should be stated first and the translation into the other system should be stated second.

(c) Is it a case where interchangeability can be achieved between two series which have not identical dimensions in all respects? In such cases, the mode of designation is important, to ensure which sizes expressed in inches are interchangeable with which sizes expressed in millimetres.

(d) If it is none of these, then the correct course is to prepare two completely separate parallel series, one in inches and one in millimetres.

These remarks give some brief indication of our attitude to international standards in general. It is endorsed by a statement to British industry by the Export Panel of B.S.I. That Panel is no gathering of standards enthusiasts; it is a group of leading hard-headed industrialists and business-men. They said, *inter alia* :

"The development of internationally agreed standards in a world where national standards are rapidly increasing in scope and number is obvious sense. It provides the opportunity to secure the unification of basic requirements in national standards and so to reduce the disparities which would become increasingly damaging to international trade."

". . . . the Export Panel think it essential that this country should participate actively and with the best possible representation in the Committees of I.S.O and I.E.C. Unless we do so, we cannot expect the internationally agreed recommendations to take proper account of

the views of British industry and British exporters."

"The Panel has asked B.S.I. officials to ensure that the machinery, through B.S.I. Committees, for consideration of international standards problems, for reaching agreement on the United Kingdom viewpoint and for briefing the delegates to international meetings, is adequate and effective. While the B.S.I. can help in this way with the organisation, it is for industry to provide the drive and authority to establish forward-looking policies and to carry them through."

special features

I think I should comment on some special features of the United Kingdom's relationship with different groups of countries. Certainly, the United Kingdom has a foot in a number of camps. This arises out of our position on the periphery of Europe, in the centre of the British Commonwealth and with other special links through trade customs and language.

First, on this occasion, and very much in the forefront, at all times, is our relation to the U.S.A. We have, of course, been encouraged by the gradually increasing part the U.S.A. has been taking in recent years in this international standards work. Admiral Hussey, now Vice-President of I.S.O., has made an outstanding contribution to the work of the I.S.O. Council in guiding the I.S.O.'s affairs. In the I.E.C., the U.S.A., led there by Mr. Dick Sogge, plays a most important and constructive part. Nevertheless, we would welcome still greater participation. First, to strengthen the hand of the inch-using countries — provided that the inch countries do agree amongst themselves — and to give the proper weight of the U.S.A.'s production to the argument and the vote; second, to extend and increase the alignment of U.S. standards with those internationally agreed, as one of the means to a better balance of things. But over and above all, what is the weight of Western participation if the U.S.A. is ever absent or without interest?

Then there are the special consultations between the "A.B.C." countries (America, Britain, Canada) on fundamental engineering standards. These are of great value, over and above their defence applications, to general trade. When widened into I.S.O. recommendations, as in the case of the unified screw thread, they can exert a further influence and bring into line a wider range of countries that are accustomed to "inch" engineering. The other Commonwealth countries are kept well informed by us on the "A.B.C." discussions — Canada of course is at the centre of them — and most of these countries, it is fair to say, are ready to accept whatever is agreed between the U.S.A., the United Kingdom and Canada. In extending the scope of such agreements, we are benefiting not only ourselves but other countries also.

The United Kingdom, as I have said, is at the centre of the British Commonwealth of Nations, a community which covers, roughly speaking, a quarter of the world's population. Naturally in the Commonwealth we have our special arrangements for consultation on standards as on other matters. In many of the Commonwealth countries their standards have, initially, been built on ours and the alignment of standards in the Commonwealth is an accepted aim which we foster by a very complete exchange of draft standards, with consideration of one another's comments and by periodic Conferences. The next Conference will be at Ottawa in August - September of 1959. This activity is in no way thought of as a rival to I.S.O and I.E.C. activity, but in some cases as a preliminary to it; in others to deal with products, not covered by I.S.O or I.E.C. work, which are of special importance in intra-Commonwealth trade.

Very much in everyone's mind at the moment is the impact of the European Common Market and of the European Free Trade Area, if and when it comes about, on standards problems. The "European Economic Union" of the Rome Treaty is now a fact. This means that the six countries, Belgium, Netherlands, Luxembourg, France, Germany and Italy are committed to a full-scale operation for economic integration. This implies not only the abolition, over a period, of all customs tariffs and quota restrictions between the six countries, but the removal also of other barriers to the free exchange of goods between those countries. This is the systematic beginning to the economic integration of over 160 million people.

a dangerous concept

It is a great conception but, taken alone, there are also very great dangers in it. It could lead to a highly protectionist area, and the initial common tariff which has been fixed against goods from outside the area is less than comforting in this connection. More important, unless the wider free market to include the other countries of Western Europe can be achieved, the move of the six countries of the European Economic Union could lead to a most dangerous split in Western Europe, a split which could go much deeper than purely economic matters. We must believe that the difficulties will be overcome and that, because of the issues involved for the future of Europe, the initiative of the "Six" will lead at an early date to the establishment of a wider European Free Trade Area embracing all the countries of Western Europe.

This is the development to be expected, a development which will lead to a free European market for all the countries of Western Europe, embracing a population of nearly 300 millions. At standard of living exchange rates, the gross national product of Western Europe is about 90% of that of the United States. The manpower of Western Europe is not very far short of twice that of the United States. It is an area which, since the War, has been one of the

fastest expanding markets of the world. It has been the source of Western civilisation and its population has great inventive ingenuity. It is an area with a gross national product, at 1954 prices and exchange rates, of about 240 billion dollars, with imports from the rest of the world of 26 billion dollars and exports to the rest of the world of 20 billion dollars.

a wider trading area

What does this mean for standards? The European Free Market will give its industries access to a much wider trading area, and so create the conditions for standardised big run production to an extent not feasible before. It must mean as well that differences in standards between the countries of the area must be eliminated — and speedily. A Free European Market means that goods must pass at the frontiers without let or hindrance. It is not only tariffs, quotas and payments difficulties that must be eliminated, but also the impediments to free interchanges which result from other differences and, not least, differences of standards. We know that, in certain circumstances, standards differences can be even more of an obstacle to the exchange of goods than a tariff barrier. This obstacle has to be swept away. If existing standards differences were to continue, we can easily see what nonsense that could make of a co-called Free European Market. It would be just as if the greatest single market of today, that of the U.S.A., were to be impeded suddenly by a whole host of differing standards requirements between the various States.

This is a problem for Western Europe which Western Europe is going, I believe, to solve. I hope that Western Europe will not be left to solve it alone. Just as the full potentialities of the existing European Economic Community of the Rome Treaty countries can be achieved, and economic and political divisions avoided, only if the wider Free European Market comes into existence, so the full potentialities of a Free European Market will result only if conditions for greater trade with the outside world are not upset. That will be the standpoint of the United Kingdom. So far as standards are concerned, it must be the standpoint of the British Standards Institution. The subject will become urgent, though, and while it is easy to see the case against the creation of a regional standards régime in Europe out of line with much of that of the rest of the world, developments cannot be left to wait. There is one principal place outside Europe to which we must look if that danger of separatism is to be avoided — to the United States.

American influence

A distinguished countryman of mine, Lord Waverley, said in Philadelphia in 1954, when he led the British Delegation to the I.E.C. Jubilee meetings there :-

> ". . . . it is inevitable that on all scores American policy must profoundly influence the fate of the rest of the world. This imposes on the American nation a responsibility of a magnitude which few of those who so readily offer advice would care — or indeed could attempt — to shoulder."

I feel I may shelter beneath the same statement. It certainly is true that organisations which exist for world, not just regional, order can be made to work with full effectiveness only if the United States co-operates with a zest and interest comparable with its place in the world. There must be few fields in which the United States does not take that leading and exacting place in international work. Is this true of international standards work? I am bound to answer that the record in this respect is not clear all across the board. It is patchy, and there are some sectors in which American participation is just plain lacking.

It was George Canning who said in 1826, "I called the New World into existence, to redress the balance of the Old." He also said "Save me, oh, save me, from the candid friend." I cherish the first saying, and despite the second I am going to mention with candour, but in the most friendly spirit, a few examples where United States' participation in this international standards work is disappointing us.

As operators of international transport services — and all countries depend on efficient international transport — we regard it as one of the prime tasks of the international standards organisations to align the essential servicing and other equipment so as to speed up operation and aid safety. Important in this field, for example, is the question of aircraft instruments, the identification of gas cylinders for aircraft, the carriage of isotopes in aircraft, all matters currently under discussion in the I.S.O. Committee I.S.O./TC 20. It is a matter of great regret that the U.S.A. is not yet a participating member of this Committee of which we hold the Secretariat. Another Committee of importance to transport is that on pallets, where again we have the Secretariat but, unfortunately, the U.S.A. is not a participating member. Another Committee in the transport field is I.S.O./TC 31 — Tyres, Rims and Valves for Motor Vehicles; again we hold the Secretariat but this has been purely nominal, because we have said so far that without United States co-operation we cannot get started with the work.

In other fields also we need U.S.A. help. In contrast to the important part they are playing in the I.S.O. Committees on non-ferrous metals, they are not full participating members of the Committee on Steel, I.S.O./TC 17. The Committee has as its first task that of securing agreement on methods of test, which will later be used as the basis for tests of other metals. Valuable work has been done in the U.S.A., and their more active participation in I.S.O./TC 17 would, I am certain, benefit all concerned.

International work on materials and equipment for the petroleum industry, the field of I.S.O./TC 67, also calls for United States collaboration and for the incorporation in international standards of the pioneer work done in the U.S.A. by the A.P.I. and others. This may, as some no doubt fear, bring with it some pressure on the U.S.A. to modify their

standards in a field where their position is unique, but is it not true that they are more likely to maintain their commanding position if they collaborate rather than turn away? And even if the U.S.A. had to contract out of some of the modifications, the use of recognised U.S.A. practice as the basis for I.S.O. work would in itself be a great advantage.

If I am rightly informed, it is this reluctance to see United States standards modified that has been responsible for what we in the United Kingdom feel is a very undesirable delay in furthering the work of I.S.O./TC 11 on Boilers, of which the U.S.A. holds the Secretariat. This subject is one which is of very great importance to us and this standard is urgently needed in connection with our European activities. The United Kingdom has similar problems to yours and is similarly reluctant to change well-established practices, but an agreed minimum code, even if some countries maintain a higher level, and that is not always a disadvantage in competition, would, we feel, be worth some compromise.

Altogether, the U.S.A. is a participating member of only 43 I.S.O. Committees, or about 50%, and in some of those in which she participates directly that association is not pursued with the keenness and zest which we associate with the American people in anything they undertake. I fear it is churlish of me to give this recital, but freedom of expression is valued more in this country than honeyed phrases. This is the country which leads in industrial production, which leads, or has led, the world in the application of standardisation techniques; it is far and away the most powerful country of the Western world. I would ask of you to lead in international standards work now for, to be sure, if you do not, others will.

In addressing the Colombo plan meeting at Seattle last week, President Eisenhower outlined the new plans of the U.S.A. to promote further the economic growth of the less well-developed areas in the interests of world economic progress and peace. He said : "The United States stands ready to play its full part in this great peaceful crusade to achieve continuing growth in freedom."

I have had the good fortune to travel in recent years to a number of those countries which are less-developed industrially. These countries are remarkably "standards-minded". The international standard developed through the I.S.O. and I.E.C. has a great attraction for them. They want widely accepted standards as a means towards better sales for their export products and as the basis of economic supplies of capital goods. A comprehensive library of international standards would release them from the problem of choosing between other nations' standards (whether American, German, French, British, or other). This is, in any case, a natural reaction of national pride; an international standard belongs to all the nations. And the newer-developing countries look forward to taking an early part in the work for these international standards; it matters little that their technical contribution to some of the work would, for the present, be small compared with that of the older industrialised countries. The dignity of their contribution would be no less than ours. Shall we fail to be their collaborators and tutors?

The work of international standards is valuable and important in a wider sense than that of promoting trade exchanges. It is good from the point of view of technological advance. Each country can contribute its own special qualities and characteristics and in combination they can produce better results than if each is undiluted. It is good in that it gives the technologists of many countries who meet together one of the best means of exchanging ideas and experiences. It certainly — of this I know from experience of work in many countries of the world — leads to friendliness and understanding. This is one field of international negotiation which, for the free enterprise country, is the preserve of the technologist, the industrialist and the business man, not of the politician. Let us see what the representatives of the communities of free people can do to set the pace and to show the way.

DIARY DATES FOR 1959

June 4th ... ... **Fifth Conference of Engineers Responsible for Standards,** Connaught Rooms, London. (See Supplement to this Journal.)

June 18th/19th ... Conference on **"Quality in Industry"**, Palace Hotel, Buxton. (See Supplement to this Journal.)

August 26th - 30th ... **Summer School, Ashorne Hill.** (See Supplement to this Journal.)
Theme : **"Management Staff Education, Selection and Training."**

October 12th ... ... **The 1959 E. W. Hancock Paper,** to be presented in Bristol.
Speaker : **Mr. R. A. Banks,** Personnel Director, Imperial Chemical Industries Limited.
Subject : **"Human Relations in Industry."**

November 19th ... **The Annual Dinner,** Dorchester Hotel, London, W.1.

can work study benefit small factories?

a Paper presented to the Melbourne Section of The Institution of Production Engineers on 11th June 1958, by

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SINCE I had the privilege to speak on a similar subject during the Third Annual Productivity Conference of The Australian Institute of Management, two years ago, I have sometimes wondered what may lie hidden behind the fact that this theme "Work Study and the Smaller Business" has been raised from time to time, as now in our Institution of Production Engineers.

There seems to be something which makes people apparently doubt that work study can be applied and by its application, benefit small enterprises.

Having been honoured by the invitation to speak to you on this subject, I very well realise that work study completely lacks the glamour which surrounds other technical topics we hear so much about nowadays as, for instance, automation, atomic power and so on. In fact, if looked upon as a technique, work study is rather more a drudgery and it requires the full enthusiasm which a practitioner can possibly possess and deploy. In other words, if he does not consider work study as something like a philosophy, he won't achieve much in his work. If, therefore, what I am going to say may be dry for some of you, I apologise before I start. It may well be that my words also lack the beautiful simplicity which one could probably find in a lecture on "Can brain surgery be learned at home?" unless I answer our question of tonight — "Can work study benefit small factories?" — with a straightforward — "Yes!" I am sure I can do so, but I am not so sure whether a colleague of mine from the medical faculty could answer his question in equal simplicity.

In dealing with our question, thought should be given to the following items:

1. What is work study?
2. What is a small factory?
3. The importance of small factories.
4. The particular problems of small factories.
5. Efficiency under control.
6. Standards in a small factory.
7. What is needed to introduce work study in small factories?

When an industry is young, special initial advantages can be found in new materials and new fields, in new applications, in new design. Patents may cover the advantages for a certain time, but then competitors acquire the same designs and the advantages disappear as time goes on.

Mainly for this reason, a new technique of studying work systematically has been developed during the last 60 years. Engineers started to "produce improvements", rather than let them occur. Big and small industries had to look for the advantages of reducing production costs through making better use of their available resources.

Thus, work study was born.

what is work study?

I do not propose to find a new definition for this branch of knowledge in management, which has not changed fundamentally since I went to university 30 years ago, except by the addition of two new and rather important techniques: work sampling, in the mid-'30's; and the use of predetermined data in a method of synthesis, the latter in the main represented by Methods Time Measurement, as published shortly after the last War. Those of you who are not quite familiar with work study may be referred to Professor Mundel's explanation: "Work study is knowledge which aims at finding and defining better methods of work, measuring this work in terms of time and, employing the scientific method in both, to establish means by which data gained can be put to practical use".

As can be seen from this definition, there are two important parts: methods study and work measurement.

methods study

This is more amply described by Professor Mundel as the scientific analysis of methods of doing any work with due regard to design, materials used, sequence of operations, equipment, machines, tools, work place for each operation, inspection, transport and storage, packing, distribution; the motions used in each and with the expressed purpose of establishing a work method which may be called the best one known at the time of the study — best because it can be proved to be the cheapest or the easiest or the shortest or the simplest. There is no claim made that it is the best method in an absolute sense, because we realise that work will be improved for ever as long as human beings will endeavour to improve. But it is claimed that any work, that is, any human effort, at home, in the kitchen, in factories, on the farms, in stores, offices, hospitals — in short — everywhere, can be studied to advantage.

One well-known example may be mentioned here: self-service shops, certainly in every case, very small businesses. But someone applied the work study approach and found that housewives go shopping at particular times in the day and on particular days in the week. They queue up whilst the grocer receives the orders one by one, gets the goods, weighs and packs, and collects the money. A typical case of bottle-necking, with its tremendous waste of time, was attacked by finding ways of distributing the weighing, packing and pricing work away from the peak hours, even making the housewife, that is the customer, do the selecting and transporting herself and only leaving the collection of money to be done by the cashier. This is simpler, shorter, easier and cheaper. This new method, in turn, requires and will require improved packing, done by the manufacturer, and the scope in this field is still considered tremendous.

What about our problems of distribution ?

I know of firms who already learned from this case and studied the time, sequence and method of loading their trucks in relation to the time. Trucks could call at customers in various parts of the city and substantial savings have been made.

To attack bottlenecks is probably one of the most rewarding fields for methods study everywhere. After we have removed one bottleneck, the next one appears for an attack. There is always one bottleneck left.

work measurement

This is the procedure of determining the time required to do work by the method just described. Although methods study usually precedes work measurement, it is not always possible and advisable to separate one from the other. Methods study can lead a long way towards work improvement by its own, that is without work measurement. Work measurement, however, should never be used without methods study. Comparisons of similar methods cannot be made without both.

Both parts are used for the development of formulae, graphs, tables and other means of application in order to use the extraordinary wealth of data thus gained, recorded, arranged, evaluated, carefully checked and rechecked, etc., to greater advantage and in simpler form as time goes on.

It is:

(a) the conscious approach;

(b) the systematic study; and

(c) the employment of certain scientific or logical principles in practice which distinguish work study as we know it now, from the chance application of improvements.

But it is also these three important characteristics, which even nowadays induce some otherwise practical men not to accept work study readily as a tool of management, because they consider it academic whilst it is precise, or they don't trust it, because enthusiasts make mistakes and too many half-trained people misuse it. In fact, however, it is because they don't themselves know enough about it.

Why ? It is easy to see the performance of a new machine which does the work of two or three men. It can be watched, its performance may even be spectacular. Work study is not spectacular; it is rather meticulous work. It cannot be understood without a definite amount of serious mental effort. It takes time, and sometimes even a great deal of patience, to see what it can achieve. By rearranging layouts or whole processes, by improving methods, reduction of effort in quite considerable proportions is sometimes possible.

When work study has been completed on a job, the new arrangement looks so simple that one tends to overlook the fact that if the study had not been made, the inefficient previous method would still be in use. But this one improved job is not all that has been gained. During its study, work study has created more of its own tools in the form of graphs, charts and other data, which can now be used readily and easily for the study of other jobs, often simply as they are, in other cases in connection with other data, facts the outsider would not easily see. That is one reason why work study must be understood.

It is hard work; there is no brilliance in it, no quick results as many expect, and the solutions required are based on more and deeper knowledge.

what is a small factory ?

There is no clear answer to this question, the reason being that mass production can be performed with few people and jobbing or high-value-per-product-work with many employees.

In the U.S.A., the Bureau of Internal Revenue has established the following income categories:

Small business	...	Up to £10,000 yearly income
Medium size business		£10,000 to £25,000
Large business	...	£25,000 and over

TABLE I
SECONDARY INDUSTRIES

		AUSTRALIA 1955				GREAT BRITAIN 1956				WEST GERMANY 1950				
	No. of Employees	No. of Factories	%	No. of Employees ×1,000	%	No. of Factories	%	No. of Employees ×1,000	%	No. of Factories	%	No. of Employees ×1,000	%	
a	up to 10	36·100		143		?		?		841·000		2·185		
b	11—20	6·700	45	100	11	15·500	27	270	3·4	52·000	48	694	8·4	small
c	21—100	6·600	44	273	30	25·800	46	1·285	16·3	45·000	41	1·858	22·3	
d	101—200	900	6	122	14					6·200	5·7	854	10·3	
						12·200	22	2·543	32·2					
e	201—500	500	3·4	153	17					5·000	4·6	3·300	39·8	medium
f	501—1,000	160	1·1	109	12	1·670	3	1·151	14·6					
g	over 1,000	75	·5	140	16	1·130	2	2·639	33·5	700	·7	1·600	19·2	large
	Total for *b* to *g*	14·956	100	897	100	56·300	100	7·888	100	108·900	100	8·306	100	
	Population			9·5 Mill.				50·5 Mill.				50 Mill.		
	% *b* to *g*			9·4				15·6				16·6		
	Grand Total % *a* to *g*			11·0				?				21·0		
b—d	11—200	14·200	95	495	55	?	86*	?	48·5*	103·200	94·7	3·406	41	small
e—f	201—1,000	660	4·5	262	29	?	12*	?	18*	5·000	4·6	3·300	39·8	medium
g	over 1,000	75	·5	140	16	1·130	2	2·639	33·5	700	·7	1·600	19·2	large

* Approximated

C'wealth Bureau of Statistics, 54/55, Canberra.
H.M. Annual Abstract of Stat., 1956.
Stat. Yearbook 1952, West Germany.

Recent West German Taxation Statistics gave the following indication on the basis of yearly turnover:

11% of the total yearly turnover of West Germany from firms with a turnover under £10,000;

44% from firms with a turnover from £10,000 to £1,000,000;

45% from firms of over £1,000,000 turnover.

But we don't get very far with these figures. Therefore, I propose to accept the division into three groups: small, medium and large, and make the total number of employees the base of our deliberations as follows:

Small factories	...	Less than 200 employees
Medium size factories		201 to 1,000 employees
Large factories	...	Over 1,000 employees

To describe a small factory further, we may add the following remarks for guidance only:

Regarding size — £400,000 sales volume as maximum, or not more than £200,000 total assets.

Regarding management — a small factory should be independently owned and operated by its owners who are also its managers.

Regarding finance — the equity capital of a small factory should come from the owner-managers. It is thus obtained from ploughed back profit rather than from the share market. Before we have a look at the production of small factories, let us look at the figures in Table I.

Investigating the factories in secondary industry in Australia, Great Britain and Western Germany, I found that the official statistical figures of Australia and Western Germany are compiled in about the same way regarding classes and groups, whilst the British differ, as you see, and do not give values at all for the column under 10 employees. In all countries, the total number of employees in small factories, that is 11 to 200, amount to over or nearly half of all (see Table I).

Australia has relatively more people employed in small factories than the highly industralised other two.

The high proportion of employees in all three countries for factories in the range of 21 - 100 employees is significant, and the percentage figure of total number of employees in secondary industry to total population is interesting — 11% for Australia against 21% for Western Germany, which may convey that Western Germany is relatively about twice as industrialised as Australia on the basis of population. But whilst its population is 10 times that of Australia, this does not convey that the capacity of German secondary industry is 20 times bigger than the Australian. For this purpose we would need more and other figures.

TABLE II
GROWTH OF METAL FABRICATING INDUSTRIES IN AUSTRALIA

Size: No. of Employees	1946 No. of Factories	1955 No. of Factories	Growth %
up to 10	2,502	5,122	104
11—200	1,858	2,747	47
201—1,000	139	170	23
over 1,000	11	18	64
No. of Employees	**No. of Employees**	**No. of Employees**	
up to 10	11,600	21,600	86
11—200	75,900	105,100	38
201—1,000	50,600	63,900	26
over 1,000	16,700	26,900	61

During the years 1946 to 1955, the number of metal fabricating factories grew in Australia as shown in Table II.

We find the most vigorous growth on both ends of the scale, that is with the small and the large metal fabricating factories, whilst the number of medium size factories did not grow half as fast.

All in all, let us remember one figure from Table I: 495,000 men and women employed in small factories in Australian secondary industry, that is 55% of all employed, not counting 143,000 in very small factories. The vast majority of enterprises in all Western countries is small and this applies equally to the U.S.A. All figures indicate that there does not exist a frightening tendency that smaller industries are going to be killed by large enterprises or combines, even in highly industrialised countries.

However, there is no doubt that behind the statistical figures much fighting for survival on the part of small and smaller factories is hidden. But small factories are not only important because of their numbers.

If there were only large factories, the range of goods available would be quite drastically smaller. A very great number of goods now available would simply disappear. The consumer would no longer be free to choose according to his tastes and means. If we, as consumers, want to decide what we wish to buy, a great number of small factories must be there and must produce profitably, and each factory must try to give the highest possible value for the lowest possible price. From this concept spring new ideas, new products, new services.

Small factories are also important because large firms depend on them for the supply of parts and goods in which they specialise. If large factories tried to produce every part of their products, the volume of some parts would be small and consequently the cost would be high. The resulting strain on the large business could be great enough to cause failure. Therefore, it can certainly be said also that large and small factories depend usually on each other. There is a need for both.

Small factories have their peculiar problems, simply by smallness. Where there are few employees, there is plenty of personal contact, a great advantage in many ways. The line of communication is short and therefore verbal instructions are preferred to written ones. Consequently, records are rare and, if they exist, sketchy. You probably know of little greasy notes or notebooks in the shop with the page loose or missing when needed. Methods study would soon overcome this, by what I term "its recording attitude". In methods study, a start is made by building up a library of work records as the most important tool.

The very size of a large firm lessens the importance of the individual. In small firms, all problems are more personal. In general, small firms select their employees less carefully and give them less training than needed. The quality of supervision is often lower than in large firms. In the main, they are weaker in the sphere of middle management. The best mechanic may have been made foreman just because of a particular know-how, not because he is also a leader of men. Methods study and later work measurement would provide plenty of material for training purposes.

Small firms are usually short of expertness, that is: their expertness is lop-sided. There isn't enough money or sufficient need to hire a really outstanding engineer or accountant or what may be required. Often the owner himself has one outstanding skill; he may be an able salesman or a first-class designer or a very good production man, but he and other members of the top group in a small firm must make decisions in fields every day where they are not, themselves, experts.

Everyone above the operator level in a small factory is usually loaded with a multitude of functions, because all the functions must exist in principle just as they exist in large factories.

One obstacle is time, or so it seems. Is it really lack of time? Is it lack of middle management? Is it just the fact that the organisation is not growing evenly in all directions or functions according to its size?

Large companies respect and rely on experts. If they don't have a specialist on the staff, they hire one, but managements of small companies often seem

to mistrust outsiders with previous experience in other fields. They seem to cling to traditional ways.

Of course, there are exceptions, hundreds of them, and by stating such circumstances and conditions, I beg to be understood in the right way. I do not say they all exist in one firm, but they exist too often here or there. However, what is a handicap need not be a defeat. What is needed is often nothing else but the way to liberate energies, a way to combine the efforts of all members of a group. Work study can be a way to overcome some of the difficulties. The greatest problem is not lack of time; it is making a start.

Probably the biggest difficulty for the smaller factories is found in the demand of efficiency and cost reduction forced upon them by large enterprises. This is, to my mind, their management problem number one.

Mr. Lewis T. Wright, in his Chairman's Message to the British Productivity Council, said, in December, 1957:

"We cannot afford to neglect any approach that might serve to improve our industrial efficiency. Our biggest firms not only pursue a continuing policy of capital investment, but they pursue also a continuous policy of work study approach. It is mostly among the smaller undertakings, where work study can make an important contribution to increased efficiency, that need is the greatest. It has been stated that very few of the smaller firms have given any consideration to work study methods. I am quite sure that every one of them could find a useful application of work study methods — an application that could make work easier, reduce costs and increase earnings. The problem is to persuade them to take a look at these techniques, but it is better if they

TABLE III
LABOUR BUDGET — 1st July '57

Function	No.	% Indirect	Hrs. per week	Rate £/wk.	Total £/wk.
Foreman	1	100	40	22 0 0	22 0 0
Leading Hands	1	20	40	17 10 0	17 10 0
	1	30	40	17 0 0	17 0 0
	1	80	40	17 0 0	17 0 0
	1	100	40	18 0 0	18 0 0
1st Machinists	7	—	280	16 0 0	112 0 0
2nd ,, ...	10	—	400	15 0 0	150 0 0
3rd ,, ...	12	—	480	14 0 0	168 0 0
Female Operators ...	3	—	120	11 0 0	33 0 0
Apprentices	3	20	120	7 0 0	21 0 0
Total	40		1,600		575 10 0
Rate per hour in sh.					7·19

Indirect Labour		Details	Hrs.	
Supervision		Foreman	40	
Leading Hands	1	20%	8	
	1	30%	12	132·0
	1	80%	32	
	1	100%	40	
Idle Time		—	—	
Overtime		—	—	
Cleaning M/cs. and Floor		20 min. p. wk. and Employee (35)	11·7	11·7
Rework		—	—	
New Employees (Learning)		20% for each Apprentice (3)	24	40·0
		30 min. p. wk. and Employee (32)	16	
Transport		—	—	
Maintenance within Dept.		—	—	
Miscellaneous:				
Afternoon tea for Females		50 min. p. wk. p. Female (3)	2·5	8·3
Others		10 min. p. wk. p. Employee (35)	5·8	
Indirect Labour hours				192·0

		Total Labour	= 1,600 hrs.
(a)	Less	Indirect Labour	= 192 ,,
(b)		Direct Labour	= 1,408 hrs.

$$\text{Ratio Indirect of Direct Labour} = \frac{a}{b} \times 100 = \frac{192}{1{,}408} \times 100 = 13{\cdot}6\%$$

were to take a look at it now, whilst time is with them. The initiative must come from the top and it will prove dangerous if no move is made until circumstances force it. The truth probably is that many undertakings who are doing very well at the moment don't want to undertake any exercise which may mean more work, more thought and closer organisation. This is understandable, if short sighted."

This is certainly straightforward talking.

efficiency control reports

I have presented Tables III, IV and V in order to show :

(a) a labour budget;

(b) an operator's efficiency report;

(c) a shop cost report.

The budget (see Table III) is struck at the beginning of the financial year; it should be established in co-operation with the foreman in our case — that is, he has to agree to it, because he is responsible during the year for working within the budget. It should contain all the items which he can control. The foreman is supposed to run a shop containing turret lathes of various sizes, milling machines, gear cutting machines, cylindrical grinders, surface grinders, etc. The production consists of machined parts made of steel, brass or cast iron in batch quantities from 15 to 1,000 — average 50 to 100. Work study has established standards for these and is also in the position to do so quickly for some similar products introduced as the year goes by. Smaller quantities have to be produced too, but do not amount to more than approximately 5% to 10% of all direct hours worked. They are machined by non-standardised methods.

We can readily see that the organisation could be for the production of gear boxes or similar units; it could be a component manufacturer, tool manufacturer; with other equipment it could be a press shop, or produce household goods, furniture, accessories or similar products.

In our case, the foreman has four leading hands and 35 operators. In the budget, the desired ratio of indirect to direct hours is also established. The two reports (Tables IV and V) are made weekly. Monthly reports have the disadvantage that the data reported have already become stale. They are history and no one is interested in what happened some weeks ago. For the same reason, it is also far better to receive reports to slide rule accuracy, quickly, than wait too long for precise reports.

The shop cost report in Table V is an example of what can happen when a foreman can control his costs. Three cases are shown as the results of one week each in August, 1957, December, 1957, and May, 1958.

To clarify what we are looking for and not to confuse the picture by more variables than necessary, I presumed that :

(e) actual rate of pay was constant throughout;

(d) hours worked were constant in case 1 and 3;

(g) hours allowed for production were constant in case 1 and 2; and consequently

(k) hours allowed for indirect were also constant in case 1 and 2.

Case 1 — shows 100 hours overtime worked and no bonus paid to department.

Case 2 — show no overtime worked and no bonus paid.

Case 3 — shows no overtime worked, but bonus paid.

After seeing the rather disappointing result of the week in August, 1957, with 75% direct labour efficiency, in spite of overtime, and the percentage of indirect too high with 17.25% against budgeted 13.6%, the foreman concentrated on the inefficient operators — 49% and 52% as seen in the operator efficiency report. He also tried hard on his indirect cost, part of which is overtime loading. After four months, he had some success, which was quite good for the first attempt. Overtime was avoided; direct labour efficiency rose by 4.4% to 79.4%. The overall control figure, which actually measures his own achievement, rose by 6.7% to 77.2%. Now he concentrated further on the direct labour efficiency, by training operators, switching others to jobs better suited to them and reducing indirect work hours considerably by less idle time, less rework and, finally, less learning hours, and more direct work by the best of his fellows, the leading hands, with the result that direct labour efficiency rose by another 5.6% to 85%. Percentage of indirect labour fell to 11.5% in spite of a rise of 12% of the allowance for it — 148 to 166 hours — and, the control figure for the foreman rose by 4.2% to 81.4%. This was in spite of a bonus paid of an amount which equalled twice the amount paid for overtime loading nine months before.

Two hundred and thirty-two hours were saved or gained — 100 overtime hours, plus 132 allowed hours — which represents a capacity increase of 14.7% for an increase of 10% in direct labour efficiency and 10.9% increase in the shop overall control figure.

Quite frankly this would be a very good achievement, and it is not out of this world. At the time of introduction of method study and work measurement it would be quite feasible and, as a factory manager, I would go to the foreman and say : " Well, Jim, a job very well done ". But how many small firms — and 40 employees isn't big — have got something like this, enabling them to measure what is going on all the time ?

There is one premise, however — work must be measurable and measured in terms of a standard as shown here in total sum of standard hours allowed for all production jobs. If, for instance, the amount of work done, under non-standardised conditions (see Table IV) approaches 50% of all hours worked, the scheme loses its significance rapidly, quite apart from the fact that at a high proportion of non-standardised jobs mixed with standardised jobs, recording can

TABLE IV
OPERATOR EFFICIENCY REPORT

1st Week Aug. '57

	DIRECT HOURS				INDIRECT HOURS								Incl.
	Standard Hrs. Allowed	Actual Hrs. Spent	Individual Efficiency %	Hrs. Non-std. Jobs	Hrs. Idle Time	Hrs. Cleaning	Hrs. Re-work	Hrs. Learning	Hrs. Transport	Hrs. Maintenance	Hrs. Misc.	Hrs. Supervision + Ldg. Hands	Hrs. O/T.
Foreman	—	—	—	—	—	—	—	—	—	—	—	40·0	—
Leading Hand No. 1	—	—	—	5·0	—	—	—	—	—	—	—	35·0	—
" " " 2	25·5	25·5	100	8·0	—	—	—	—	—	—	—	12·0	5·5
" " " 3	20·0	18·0	111	—	—	—	10·0	—	—	—	—	15·0	3·0
" " " 4	10·0	15·0	66·7	5·0	—	—	—	—	—	5·0	—	20·0	5·0
1st Machinist No. 1	28·0	32·0	87·5	7·0	—	·3	—	—	—	·7	—	—	9·3
" 2	32·0	28·0	114·3	10·2	·8	·3	—	—	·7	—	—	—	11·3
: :	:	:	:	:	:	:	:	:	:	:	:	:	
: :	:	:	:	:	:	:	:	:	:	:	:	:	
2nd Machinist No. 1	:	:	62	:	:	:	:	:	:	:	:	:	
" 2	:	:	52	:	:	:	:	:	:	:	:	:	
: :	:	:	:	:	:	:	:	:	:	:	:	:	
: :	:	:	:	:	:	:	:	:	:	:	:	:	
3rd Machinist No. 1	:	:	49	:	:	:	:	:	:	:	:	:	
" 2	:	:	75	:	:	:	:	:	:	:	:	:	
" 3	:	:	:	:	:	:	:	:	:	:	:	:	
: :	:	:	:	:	:	:	:	:	:	:	:	:	
: :	:	:	:	:	:	:	:	:	:	:	:	:	
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: :	:	:	:	:	:	:	:	:	:	:	:	:	
Total hours	1021·0	1360·8	75%	89·2	25·0	12·0	10·0	60·0	5·0	5·7	10·3	122·0	80·0
Non Std. Hours	67.0												
at 75%	1088.0		1450·0					250·0					
Indirect hours a/p. Budget 1.7.57					—	11·7	—	40·0	—	—	8·3	132·0	—
									192·0				

TABLE V
SHOP COST REPORT

		1st Week Aug. 1957	1st Week Dec. 1957	1st Week May 1958
(*a*) Total Wages ... ... £		630 0 0	576 0 0	612 0 0
(*b*) Deduct (1) O/T. Loading ... £		18 0 0	—	—
(2) Bonus ... ... £		—	—	36 0 0
(*c*) Total Wages excl. (*b*) ... ... £		612 0 0	576 0 0	576 0 0
(*d*) Total hours worked ... ... hrs.		1,700	1,600	1,600
(*e*) Actual Rate of Pay excl. (*b*) sh./hr.	$\frac{c}{d}$	7·20	7·20	7·20
(*f*) Hours spent on Production ... hrs.		1,450	1,370	1,435
(*g*) Hours allowed for Production hrs.		1,088	1,088	1,220
(*h*) Efficiency of Direct Labour ... %	$\frac{g}{f} \times 100$	75·0	79·4	85·0
(*i*) Hours spent on indirect Work hrs.		250	230	165
(*k*) Hours allowed for indirect Work hrs.	13·6% of (*g*)	148	148	166
(*l*) Percentage of indirect Labour %	$\frac{i}{f} \times 100$	17·25	16·8	11·5
(*m*) Total hours allowed ($g + k$) at budgeted Rate of Pay ... £	7·19 sh./hr	444 0 0	444 0 0	498 0 0
(*n*) Overall Control Figure ... %	$\frac{m}{a} \times 100$	70·5	77·2	81·4
		Case I	Case II	Case III

become loose and requires strict control. Only the percentage calculation for indirect labour would be left intact. In our case, its absolute value is not very significant, although in other circumstances indirect labour could be higher.

The example given shows clearly that time standards are a very important tool of management. Every firm's aim, every production engineer's and foreman's duty, is to get production out. Standards in terms of time are their means of determining the effectiveness of management. Our foreman did see where things went well and where additional supervisory effort was necessary (see Table IV). He could not possibly devote his time and effort to a wrong end as he probably would if he were to act on opinion or suspicion. The clerical expenses necessary, in any firm, to compile the performance records will soon be offset by the gains which will be made by better frontline management and once a firm and its supervisory staff gets used to the guidance by standards, recording will become a routine.

This leads to the obvious question; when can standards be compiled in a small factory ?

standards in a small factory

We have said that work must be measurable. Looking at the 15 various classes of our secondary industry, I think I am not far out in saying this :

In the production of basic material and chemicals, small factories play a minor role. But in those classes which produce metal goods, machines, conveyances, textiles and textile goods, clothing, food, joinery, stationery and similary processed goods, their role is very significant.

The 15 classes of industry are, in the main, producing new goods and do very little, probably far less than 5% repair work for their customers.

With regard to their production methods, I suppose that 40% of all small firms produce finished articles in small batch production, 50% in large batch or even mass production, and the other 10% basic materials.

As soon as work done is repetitive, it can be systematically method studied and measured. One of the first questions is whether or not it is desirable to study a particular job in an attempt to improve it. The first thing to learn in making a study is the expected life of a job. It is pointless even to begin a study if the job is likely to be discontinued because the part is to be redesigned or superseded or rendered obsolete. It requires a certain time to study the job, to develop methods of improving and to put the improved method into effect.

If it is likely that the operation will continue for a reasonable length of time, the next thing to determine is the amount of money per year to be spent upon the operation. This thinking in terms of per year is important. We gain a greater perspective by "thinking in per year terms" and we are able to find the most promising field for investigation.

The money being spent per year is fixed by the repetitiveness of the operation, the length of the operation and the labour rate.

The more repetitive an operation, the greater can be the detail in which it should be studied. For a given amount of repetition, the higher the hourly labour rate, the more profitable it will be to make improvements.

Let us be quite clear on this. Repetitive is not meant merely with regard to a product or part, but it can also be an operation on various parts or products or the elements of an operation. The time element for closing a collet or revolving the turret on a turret lathe is repetitive in this sense, and on a certain model of a turret lathe, by the way, the same in Melbourne, London and New York. I feel it would be highly appreciated if machine tool makers would disclose to their customers standard data for the operation of their machines. It has been done in some cases, but in general at present every user has to build all data up himself, and that from scratch. In any case, modern machine tools are designed along this line of thought; therefore, the suggestion of publishing the basic data behind the design does not seem out of place.

When quotations for special purposes are made, the maker must use his data, anyway. It would be a great help and, I would say, a welcome stimulation to use the work study approach more widely, if the

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Mr. Hoch, who is one of the founders and a Past Chairman of the Work Study Section of the Australian Institute of Management, studied mechanical engineering at T. H. Danzig and T. H. Dresden, specialising in production engineering under Professor Dr.-Ing. E. Sachsenberg. He graduated with honours in 1928 *and gained a scholarship for post-graduate work at the M.I.T. in Boston, Mass.*

For several years Mr. Hoch worked in the U.S.A. as designer of special machines and tools with Mesta Machine Company, Pittsburgh, and General Motors in Detroit and Flint. In 1934 *he joined the Wanderer-Werke A.-G. in Chemnitz, and was appointed Sales Manager, and later Works Manager, in the machine tool division. He was a member of several Standards Committees and participated in research work on job evaluation and the standardisation of machine tools.*

In 1948, *he migrated to Australia and is now Manufacturing Manager of The Sutton Tool & Gauge Manufacturing Company Pty. Ltd., Melbourne.*

machine tool industry would take the lead and supply special slide rules, charts, graphs, tables, nomographs, more often instead of, for instance, distributing calendars, lighters or pencils.

Just recently we were not a little surprised when our work study boys found that the actual r.p.m.'s of a certain lathe deviated from the stated ones in their range from nothing up to 12% plus and minus. Another similar case happened on a milling machine, where the feed rate was stated at $1\frac{1}{8}$ in. per minute and was $1\frac{1}{2}$ in. per minute in reality.

These are examples showing how work study, through its meticulousness, educates to precise calculating and thinking, because, as you can well imagine, our standards would have been wrong if we had not found out. Such an approach also helps considerably to win the confidence of the operators.

This leads us to another important point: foremen must know all about how the standard is arrived at in order to explain, correct and to run their departments effectively.

There is no principal difference in the application of work study in a large factory or a small factory; there is also no difference in what can be expected as a gain. In a small factory which makes toys by the hundreds of screws by the ten thousand or zip fasteners by the mile, work study is just as essential as it is in a big automobile factory and if medium size and large factories, to my mind, cannot afford to function without work study techniques, small enterprises cannot either. They have shown initiative and imagination in putting their products on the market; they have worked out certain methods, some probably very ingenious. Sales are fine, but there is competition, and if there isn't, there will be.

Managements know what their articles cost and what they can cost on the market. But, do they always know what they *should* cost? To find that out, they have to decide to study their methods further, with a fresh approach, this time consciously, as a task of its own undertaken by someone who is specifically trained to study and to evaluate his studies in the form of measurements.

Let us be quite clear about one important point: work study is not a substitute for good management, neither in large nor in small factories. It cannot "spark off" a will to change, for instance. Initiative must do this "sparking". Work study is only a tool of management, but it is an important one, insofar as it will give management reliable data to work with, maybe to suggest further "sparks" in the minds of managements of initiative.

what is needed to introduce work study in small factories?

I have been asked this question many times, but there is only one answer — competent work study engineers. One member at least of the staff must be trained in the techniques, have the suitable personality and possess at least two years' practical experience in work study. What he can achieve in a given factory and a given time depends entirely on the amount of study work to be done and this depends on the type of production, its variety and its size, that is, the number of operations and so on involved. It is not possible, therefore, to conclude generally that one work study engineer goes with a certain number of employees. It can be one to 50 or one to 100 or more.

Have we got them in Australia?

I am afraid not nearly enough, with regard to what the Work Study Section of the Australian Institute of Management considers to be a competent work study practitioner. We must realise that work study is a very young field of knowledge in this country. A survey undertaken two years ago by the Section showed that prior to 1951 work study was used rather spasmodically, but has gained momentum very considerably since. Between 1951 and 1957, the Royal Melbourne Technical College has graduated 179 students in methods study and 86 of them in work measurement also, and is training at present 98. Training by consultants may have amounted to 500 to 800 in the same period. I would estimate that there are not more than 1,000 fully experienced work study engineers practising in Australia at present.

The assumption that they work in factories of 21 employees and more gives us the following equation:

$$\frac{797{,}000}{1{,}000} = \frac{800}{1}$$

which is the number of employees per work study engineer in Australia now. This figure corresponds quite well with the ratio found by the survey of the Section for 41 companies which actually used work study in 1956. The ratio for them was 205 : 1.

A recent report from Germany on the occasion of the Annual Conference of R.E.F.A. in 1957 states that in West Germany, R.E.F.A. comprises at present 70,000 work study engineers of about the same professional background as the membership and associated membership of the Work Study Section of the Australian Institute of Management requires. In fact, their qualifications are even higher, as they are required over there to be 28 years of age minimum, instead of 25 years in Australia and a psychology test must be passed before training even starts.

For West Germany, the ratio is 7,612,000 to 70,000, that is 109 to 1. Certainly the R.E.F.A. idea is now 36 years old; the organisation has been going from strength to strength since long before the War and we here are doing a lot to pick up. However, much more remains to be done in training more work study engineers and I hope that in 5 to 10 years' time, many more engineers will be available if Australian industry supports their endeavours vigorously. To reach West German levels would mean that we need 7,300 competent work study engineers in this country for our secondary industry. The survey of the Section and a critical appraisal of the German figures just mentioned suggest that in Australia, work study is fairly extensively applied in medium and large enterprises and in but very few smaller ones; whilst 70,000 in Germany cannot

TABLE VI
EFFICIENCY RATING CHART

	% Skill	% Effort	% Conditions	% Consistency	Total Range %
A_1	+15 Super	+13 Excessive	+6 Ideal	+4 Perfect	138
A_2	+13	+12			135
B_1	+11 Excellent	+10 Excellent	+4 Excellent	+3 Excellent	128
B_2	+8	+8			123
C_1	+6 Good	+5 Good	+2 Good	+1 Good	114
C_2	+3	+2			108
D	0 Average	0 Average	0 Average	0 Average	100
E_1	−5 Fair	−1 Fair	−3 Fair	−2 Fair	89
E_2	−10	−8			77
F_1	−16 Poor	−12 Poor	−7 Poor	−4 Poor	61
F_2	−22	−17			50

According to Methods Engineering Council, Pittsburgh.

possibly be employed in large factories alone, but are spread more widely down to small enterprises because once work study has been introduced, and is working in a factory, in many instances one study engineer can look after the work of more operators than during the initial stages of introduction.

So there is one warning : unless there is a considerable increase in the number of students of work study, it would not be possible to satisfy a rising demand if small factories wanted to apply work study at a greater rate than at present. To believe that some training in this field would be sufficient, let us say a four weeks' training course or so, and start to introduce half-measures with insufficient and incompetent people, would be utterly unwise. Enough damage has been done in that way in the past in other countries and we should do everything possible to avoid half-measures in Australia.

Work study deals with people more than with machines and equipment, because we want to improve the effectiveness of human effort. He who is not able to sell the idea behind work study to his men is on the way to trouble, and the idea is, as Professor Mundel said : " to establish a work method which may be called the best one known because it can be proved to be the cheapest or the easiest or the shortest or the simplest and then to determine the time required to do the work by following this method ". The stress is definitely on the methods, the measurement side should be considered as the rather obvious result : a better method in a better time. To raise the level of actual achievement is our aim. Therefore, we must know where achievement is below average and by how much.

Table VI shows the rating scale of the Methods Engineering Council, Pittsburgh, which is used in Methods Time Measurement and I refer to those 49% and 52% operators in Table IV. The point is that the law of probability does not apply to small populations; in other words, whilst a large firm of say, 1,000 or more people, can reasonably expect to be manned according to a cross-section of the population, a small firm can find itself manned lopsidedly, that is, below average and not being aware of it. This shows that the necessity to measure the effectiveness of the human effort is even more important for a small number of people than for a large one. If large firms use methods study and work measurement procedures and small ones don't, the discrepancy can become even greater, because large factories would raise the level of average and the small factories may not even know where they stand. The usual point made, that a good foreman knows who is good and who is not, is subject to the fact that he himself is very good and also means he is using a yardstick which is not controlled in itself.

From whatever angle we may approach the question, the answer remains the same : if work can be measured, one should use work study. All factories producing in repetitive fashion, that is, in repeating batches and repeating processes, should use work study. That means that small factories of this type can benefit from the following advantages :-

1. improvement in methods systematically and consciously;
2. improved operator effectiveness;
3. the setting of standards for the selection of operators;
4. the setting of production schedules;

5. the definition of objectives for supervisors;
6. the comparison of methods;
7. the determination of standard costs;
8. the determination of labour and machine requirements;
9. the calculation of the number of machines an operator should operate;
10. the balancing of the work of groups of operators, simultaneous or in sequence;
11. the provision of a basis for paying incentives, if wanted.

Now, what about those small firms that do not produce goods in repetitive fashion and where, therefore, work measurement, either by using orthodox time study, or by using predetermined, synthesised standard data, is not readily applicable ? There is certainly the possibility of using methods study in a number of directions. There is the problem of plant layout.

This problem is almost always present in small factories. It is their problem of growth, when a department is to be added and a new product introduced or new machinery added. Thousands of small factories all over the world have grown and are growing so fast that their " seams " burst every now and again. After some years, transport and supervision become real organisational problems adding considerably to cost.

There are three distinct layout solutions :

1. *continuous process layout*

The processes and their sequence determine the type of layout. The production of cement is one example; bakeries are another. It is typical for the chemical industry, but is rather the exception in most of the small factories.

2. *process type layout*

All like machines and operations are grouped together in one department. The products travel from department to department. This is the oldest type of layout and practically every small place starts with it. The danger is hanging on to it for too long.

This layout is best suited :

1. for products which are not standardised;
2. for low volume production;
3. for products which are subject to frequent changes.

Its advantages are :

1. fewer machines of each type are required;
2. foremen and operators become rather specialised in the operation, set-ups and maintenance of their machines;
3. flexibility is high;
4. costs at times of low production can be low.

Its disadvantages are :

1. costs for material handling and transport are considerable;
2. much attention must be paid to scheduling and routing;
3. more floor space is required for the same amount of output for storage of banks of material, consequently more work is in progress;
4. more aisles are necessary to accommodate transport;
5. inspection is increased as responsibility is divided up;
6. sometimes a very complicated system of production control is necessary.

3. *product type layout*

Equipment is grouped according to sequence of operations on a product, or a product group. Products travel from one operation to another over definite routes. This layout is best suited for standardised products or product groups. Volume is the criterion.

The advantages are :

1. materials handling is reduced to a minimum;
2. delays show up easily;
3. banks of work in progress are reduced;
4. floor space required is low;
5. production control is simple.

The disadvantages are :

1. investment for machinery may be high;
2. in case of breakdown, downtime of a line may be high;
3. flexibility is limited when machines are grouped to produce one product only;
4. costs can be high, if production is low;
5. supervision may not be highly efficient if one man is required to supervise different types of complicated machines and operations.

The plant layout of a small factory can almost always be improved by methods study, using its techniques of process charts, string diagrams, etc., in studying the usage of machines, the distance products must travel, the storages necessary, and the efforts necessary to control the flow of material. You will probably be surprised to hear that a small firm employing 150 hands on the floor, found by investigation that its product batches travelled altogether during one year the distance from Melbourne to Perth and back, not by car, nor by rail or aeroplane, at the speed a mother pushes a pram and not in a straight line, every 20 yards turning a corner, every 50 yards opening and closing a door, with the transport men bending down and lifting one or more containers at the same intervals. The one consolation

TABLE VII
FIELDS AND CLASSES OF WORK STUDY APPLICATION

1	2	3	4	5 ←—Field	
Materials and Supplies	Design	Sequence of Operations	Workplace, Machines, Tools	Operator's Motions	Class ↓
Change →	Change →	Change →	Change →	Change	1
—	Change →	Change →	Change →	Change	2
—	—	Change →	Change →	Change	3
—	—	—	Change →	Change	4
—	—	—	—	Change	5

M. E. Mundel

was that two, three, four or five jobs were transported as one, but still the men hiked to Adelaide and back doing gymnastics all the way.

Considerable improvements are possible by study and almost invariably the final plant layout will be a compromise between all possible equipment arrangements, between the ideal and practicable, in which costs, savings, manufacturing efficiencies and other related factors are balanced against the problem.

The problem begins to be solved, once management becomes aware of it, by putting some yardstick to it.

Material usage is another problem which can be studied. Assume we want to investigate how much fuel a bakery is using a day. Methods study would graph for this purpose, over the time elapsed during a day:

(a) the temperature of the oven;
(b) the consecutive charges and discharges of bread — their weight and time;
(c) the intervals between them;
(d) the amount of fuel charged, and when.

The sum total of weight of fuel divided by the sum total of weight of bread would give the amounts of fuel used per pound of bread; but the graph would also show the intervals between discharges and charges of bread, that is the idle times of the oven, which were not necessary for heating the oven up to required temperature. The reason was found — there was waiting time for more dough. The capacity of the oven was greater than the supply of dough. One more man engaged for making dough would have cancelled out idle oven time and saved part of the cost for fuel. This was the immediate effect and was the purpose of the study. A secondary effect was that the total daily cycle was shortened and bread was available for delivery to customers earlier than before, which may have been even more important to the small bread factory. The graphical method of work study brought the significance of each detail to light.

I suppose some of you will say: that's production engineering — definitely. I agree. Work study and particular methods study is a branch of production engineering. But I may add this — production engineering is predominantly a line function; work study is predominantly a staff function. In methods engineering and work measurement the stress is more on fact finding by specialists in an advisory capacity for the production people as doers. The idea is that someone takes all his time and knowledge to chase improvements, waste, delays, idle times, not distracted by other important duties or functions, highlights them and makes the doer aware of them.

delays

In small batch and speciality production, one of the most rewarding fields for study is with regard to delays. Operators, machines and components are idle for certain times and for various reasons.

1. Operators are idle:
   (a) whilst the machine is running;
   (b) because of a breakdown;
   (c) because of various avoidable delays — tools not available, tool not sharp, drawing not clear, etc.;
   (d) recreation allowance necessary;
   (e) personal allowance.
2. Machines are idle:
   (a) caused by operator (see 1 (c), (d) and (e));
   (b) machine broken down;
   (c) machine out of commission;
   (d) caused by process;
   (e) stopped for loading, or measuring.
3. Components are idle:
   (a) caused by operator (see 1 (c), (d) and (e));
   (b) because of machine breakdown;
   (c) caused by process — too large batches, work place layout;
   (d) in storage:
      (i) in stores,
      (ii) at workplaces;
   (e) in transport.

Such delays happen in every activity, certainly, also in small factories, and work sampling or ratio delay studies are the techniques to attack them. Thorough training in these techniques is essential. The outcome is allowances properly established. Allowances expressed in percentage of base times are perfectly legitimate. They can run up to 200% in extreme cases, and they are particularly significant in one-off production.

The time for every job can be broken down into three parts:

1. Make ready.
2. Do.
3. Put away.

1 and 3 are usually combined as so-called "set up time". Very often the "do time" is very small in comparison to the make ready and put away time. Tool designers, production engineers and foremen can find a rewarding field for savings by looking at this point consciously when aiming at job improvements, by reducing and even eliminating both. We have to bear in mind that allowances have to be made, not only to the "do time", that is time per piece, but also to the set up time. These percentage allowances are naturally high in factories which are not too well organised and which have weak supervision.

In small batch production, it might not be overlooked that the operator needs a certain time to get into the swing of doing his job. With the first few pieces, he takes more care and works more consciously than later, when subconsciously he is better aware of what he is doing. An allowance should be made for it and added to the set up time, this being applicable to any batch quantity that follows, because it might well be that not always the same quantity of parts is to be produced in future.

It can be said, generally, that in large batch production allowances are in the range of 5% to 10%. In small batch production, they are never lower than 15%, usually in the range of 20% to 75%, which may serve to show the necessity for further investigation. For one-off production, I would not like to state a percentage.

I have not dealt with the techniques of work study in detail. They are all more or less graphical or mathematical devices to result in its more efficient application. They are in themselves, no end, but means to an end; that is, procedures for analysing jobs and setting job methods to aid training operators to follow the established methods, to determine the time a job should take and to control standards of method and time.

fields and classes of work study application

Before I close I would like to summarise what has been said, and try to define the fields of work study application. They will show more clearly where work study can help small factories. Table VII shows the five fields — materials, design, processing, workplaces and operators.

A change of material is followed by changes in all other fields; this class 1 - 1 change is the most radical or influential usually of all. So is a design change class 2 - 2. We see in this chart the significance of changes with which work study does concern itself. It is not the class 5 - 5 change only, that is, operators hand and body motions, as usually and quite wrongly assumed. This is where so many people are misleading themselves by thinking of a time observer who stands by with a stop-watch and deals with seconds to speed up operators. The chart shows quite obviously that work study is supposed to be applied over the whole field of performances. It is a technique that should be understood by all concerned with creating co-operative action on the different levels of responsibility in a factory, although it should be applied only by those who are well trained in it.

In conclusion I think the question posed in the title of this Paper should be answer as follows:

1. Small factories employing more than half of all employees in Australian secondary industry should avail themselves of all possible means to increase the effectiveness of human effort, work study being one of the most important means to this end.
2. Methods study, work study's first part, should be consciously, that is systematically and logically, applied in every factory.
3. Work study, that is methods study and work measurement, should be applied wherever a survey of activities in terms of occurrences per year shows significant repetitiveness.
4. To make 1, 2 and 3 possible in small factories, our country must train more work study engineers. Industry and its management should give their full support to training and education in this field and, I think, The Institution of Production Engineers should be the most active supporter of all.

LITERATURE

1. Mundel, M. E. "Motion and Time Study Principles and Practice." 1955.
2. Commonwealth Bureau of Census and Statistics.
   (a) Secondary Industries, 1954 - 1955.
   (b) Metal Fabricating Factories, 1954 - 1955.
3. Her Majesty's Annual Abstract of Statistics, 1956.
4. Statistisches Jahrbuch der Bundes Republik Deutchland, 1952.
5. Gotterer, M. H. "Profitable Small Plant Management." 1954.
6. Commonwealth Department of Labour and National Service. "Australia's Experiences With Wage Incentives." 1951.

COUNCIL NOMINATIONS

NOTICE OF COUNCIL ELECTIONS 1959 - 1960
NOMINATIONS †

(a) In accordance with Article 43, nominations are invited to fill *nine* vacancies for Elected Members to serve on Council for 1959 - 1960 (i.e., eight Members and one Associate Member).

(b) Before candidates are nominated for election, their consent must be obtained.

(c) Candidates for election must be nominated in writing by three * Corporate Members of the Institution.

(d) In addition to nominations as in (c) each Section Committee may nominate one candidate.

(e) The nominees must give the full Christian names (or forenames) together with respective addresses of the person or persons they are nominating.

(f) The nomination must be accompanied by brief biographical notes of the persons who have been nominated.

(g) Nominations must be set out on a separate sheet of paper and not included in a letter dealing with other subjects.

(h) Nominations must be contained in a sealed envelope marked "Council Nomination".

(i) Nominations must reach the Secretary at 10 Chesterfield Street, Mayfair, London, W.1, not later than 18th May, 1959.

(j) The members listed below are due to retire and are not eligible for re-election as Elected Members until at least one year has elapsed.

Members

L. R. Evans; E. F. Gilberthorpe; F. Grimshaw, O.B.E. (resigned, January, 1959); H. B. Harris; R. E. Leakey; L. S. Pitteway; R. H. S. Turner.

NOTE — H. Bainbridge, who was elected in July, 1958, has resigned.

Associate Member

G. V. Bevan.

By Order of the Council,

W. F. S. WOODFORD,

Secretary.

May, 1959.

* Corporate Members are: Honorary Members, Members, Associate Members.

† See also page 283.

HONOUR FOR PAST PRESIDENT

The Council and Executive Committee of the City and Guilds of London Institute have conferred upon **Dr. Herbert Schofield,** C.B.E., Past President of the Institution, the Insignia Award in Technology for his work in Structural Engineering. Only five of these Awards are conferred annually, the recipients being persons of distinction, in recognition of outstanding achievements in one of five special fields — Chemical and Metallurgical Industries; Constructional Industries; Electrical Industries; Mechanical Industries; and Textile Industries.

Dr. Schofield, who was born in Halifax, Yorkshire, was educated at the Trinity Higher Grade School of that town, and afterwards at the Royal College of Science, London. He became an A.R.C.S. in Mechanics, Mathematics and Physics (1st in First Class, and Mechanics and Physics Prizeman). He was a Whitworth Exhibitioner and gained the D.I.C. for original research.

In the course of his career, Dr. Schofield has done important work in the field of the Constructional Industries. He was elected to full membership of the Institution of Structural Engineers in 1926, and has served on the Council of that body, and was formerly a member of the National Trade Advisory Committee for Engineering and Shipbuilding.

For many years, Dr. Schofield was Principal of Loughborough College, an establishment which he did much to build up, and with which his name will always be associated. He was President of the Institution of Production Engineers from 1948 - 50, and the Schofield Travel Scholarships — which offer Graduate members of the Institution the opportunity of studying production engineering for six months in a country other than their own -- were established by the Council as a permanent tribute to Dr. Schofield's contribution to the activities and development of the Institution.

(continued overleaf)

COUNCIL NOMINATIONS — continued

PARTICULARS OF MEMBERS OF COUNCIL OF THE INSTITUTION 1959/60

This information is given in accordance with Article of Association No. 37. It is compiled from details available up to 21st April, 1959. None of the members shown on this list should be nominated as Elected Members of Council.

PRINCIPAL OFFICERS

President: G. R. Pryor.
Vice-President: H. Burke.
Chairman of Council: H. W. Bowen, O.B.E.
Vice-Chairman of Council: R. H. S. Turner.
Immediate Past Chairman of Council: H. G. Gregory.

ELECTED MEMBERS

The following Elected Members will continue in office for a further year from 1st July, 1959:

G. R. Blakely	P. H. W. Everitt	R. N. Marland
J. V. Connolly	B. C. Harrison	Dr. T. U. Matthew
E. P. Edwards	E. Levesley	R. J. C. Whitaker

CHAIRMEN OF REGIONAL COMMITTEES ADDITIONAL REPRESENTATIVES ON COUNCIL

At the time of going to press the election of Regional Officers had not been completed. The information available is shown below:

Northern Ireland

J. L. Fromson, Short Brothers & Harland Ltd., Hawlmark Works, Newtownards, Co. Down.

21st April, 1959.

HALIFAX & HUDDERSFIELD DINNER - DANCE

The occasion of the Halifax and Huddersfield Annual Dinner - Dance, held at the White Swan Hotel, Halifax, on 27th February last, was a very happy one. The chief guests were: Mr. J. B. Scott, D.F.C.; Mr. E. W. Hancock, O.B.E., Past President of the Institution; and Mr. I. G. Hopkinson, Regional Chairman. The gathering, which included a number of prominent industrialists, again successfully fulfilled its function as an important part of the Section's proceedings.

In the photograph (left) are (left to right): Miss N. E. Bottom, the Section's Social Secretary; Mr. A. E. Clifford, Section Chairman; Mr. J. B. Scott; Mrs. Clifford; Mr. I. G. Hopkinson; and Mr. E. W. Hancock.

NEWS OF MEMBERS

Mr. J. P. Ford, Member, has been appointed to the Board of Coventry Climax Engines Limited. He is also Managing Director of Coventry Climax International Limited.

Mr. G. C. Oram, Member, at present Manager of the central engineering workshops at Appleby-Frodingham Steel Company, has recently been appointed to the new position of Works Manager (Production Services). He will continue to act as Technical Consultant for Engineering Workshops to The United Steel Companies Limited. Mr. Oram is a Corresponding Member of the Institution's Papers Committee.

Mr. F. W. Prakel, Member, has established the firm of F. W. Prakel & Associates, Methods and Production Consultants, Johannesburg. Mr Prakel would be pleased to meet any newcomers to South Africa and would be pleased to assist them.

Mr. Harry Shaw, Member, formerly Joint Managing Director of The Midland Saw & Tool Co. Ltd., and High Duty Saws Ltd., has been appointed Chairman of both Companies.

Mr. F. R. Ball, Associate Member, has taken up the position of Works Manager of Wellworthy Limited, Lymington, Hants.

Mr. A. Beaumont, Associate Member, has taken up an appointment as Technical Representative of Coventry Climax Engines Limited for the Yorkshire area.

Mr. K. A. Crago, Associate Member, has relinquished his position with the Tilley Lamp Co. Ltd., to take up an appointment as a Methods Development Engineer with A.E.I.-Hotpoint Limited, Peterborough.

Mr. H. T. Hill, Associate Member, has recently taken up an appointment as General Manager of Wellworthy Limited, Lymington, Hants. He is also on the Board of Directors.

Mr. B. V. Mahabale, Associate Member, Chief Metallurgist and Works Manager (Foundry) of Messrs. Mysore Kirloskar Limited, Yantrapur, P.O. Harihar, is visiting the Continent and England. He will be working in a number of firms on the Continent and he will also visit the U.S.A. Mr. Mahabale has been, for the past 14 years, the Chief Metallurgist of Messrs. Mysore Kirloskar Limited.

Mr. W. M. Stern, Associate Member, has recently been appointed Assistant Works Manager of Hayward, Tyler & Co. Ltd., Luton. He was formerly Head of Production Control.

Mr. A. Turner, Associate Member, has been appointed Director of High Duty Saws Ltd., and is also a Director of The Midland Saw & Tool Co. Ltd.

Mr. Cyril Spector, Associate, Senior Lecturer in Management Studies at the College of Technology and Commerce, Leicester, has been appointed Head of Department of Administration at the London School of Printing and Graphic Arts.

Mr. J. Cartwright, Graduate, is now an Assistant Lecturer Grade "B" at Bury Technical College.

Mr. E. G. Holt, Graduate, has relinquished his appointment with The Patent Shaft & Axletree Co. Ltd., and has taken up an appointment as Assistant Lecturer in Production Engineering at the County Technical College, Wednesbury.

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1958/1959

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H. W. Bowen, O.B.E.

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R. H. S. Turner

Immediate Past Chairman of Council

H. G. Gregory

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South Eastern
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S. G. E. Nash
Wales
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Midlands
T. W. Elkington
North Western
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South Eastern
J. L. Gwyther

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E. F. Gilberthorpe H. B. Harris B. C. Harrison R. E. Leakey E. Levesley R. N. Marland Dr. T. U. Matthew
L. S. Pitteway R. H. S. Turner R. J. C. Whitaker

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New Zealand
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C. A. Gladman, E. J. W. Herbert, A. G. Jones, J. S. Murphy, A. E. Newcombe, F. W. Penny, C. Pullen

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Midlands ... ... A. C. Turner
North Midlands ... ... C. N. T. Manfull
Northern ... ... A. Smith
North Western ... ... J. P. Speakman
Northern Ireland ... ... J. G. Easterbrook
Scotland ... ... J. Nicolson Low
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Melbourne Graduate (Victoria Australia)	E. K. Stephenson, 5 Olinda Street, Glen Waverley, Melbourne, Victoria, Australia.
Sydney (New South Wales)	K. G. Slorach, 98 Church Street, Castle Hill, New South Wales, Australia.

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Canada	Frank R. Taylor, 67 Wasdale Crescent, Apt. 5, Toronto 19, Ontario, Canada.

INDIA

Bombay	C. R. Pal, The Crescent Iron & Steel Works Ltd., Goregaon (East), Bombay, S.D., India.
Calcutta	P. J. O'Leary, c/o Guest, Keen, Williams Ltd., 41 Chowringhee Road, Calcutta, India.

NEW ZEALAND

New Zealand	G. Stedman, 3 Harrison Avenue, Belmont, Takapuna, Auckland, New Zealand.

SOUTH AFRICA

South Africa	A. Aitken, 209-211 Pharmacy House, 80 Jorissen Street, Johannesburg, P.O. Box 10837, South Africa.

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Birmingham	H. W. White, "Spring Pools", 677 Birmingham Road, Lydiate Ash, Bromsgrove, Worcs.
Cardiff	C. Ll. Griffiths, "Brynteg", 139 Tyntyla Road, Llwynypia, Rhondda, Glamorgan.
Cornwall	F. G. Hawke, 3 Bellevue Terrace, East Hill, Tuckingmill, Camborne, Cornwall.
Coventry	A. S. Hopkins, 39 Oaks Road, Kenilworth, Warwicks.
Derby	P. Warburton, 16 Vicarage Road, Chellaston, Derby.
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Dundee	J. Nicolson Low, Technical College, Bell Street, Dundee.
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South Essex	F. Hopkinson, "Woodley", 40 Highfield Road, Chelmsford, Essex.
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Tees-Side	J. H. Cooper, 48 Hob Hill Close, Saltburn-by-the-Sea, Yorkshire.
Western	A. Eustace, 19 Ferndale Road, Northville, Bristol, 7.
Wolverhampton	W. T. Vaughan, "Windsor", 24 Windermere Road, Palmers Cross, Tettenhall, Staffs.
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CORRESPONDING MEMBER IN WEST AFRICA

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P.O. Box 202, Takoradi, Ghana, West Africa.

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Leeds	T. Robinson, 764 York Road, Leeds, 15.
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Honorary Secretary:
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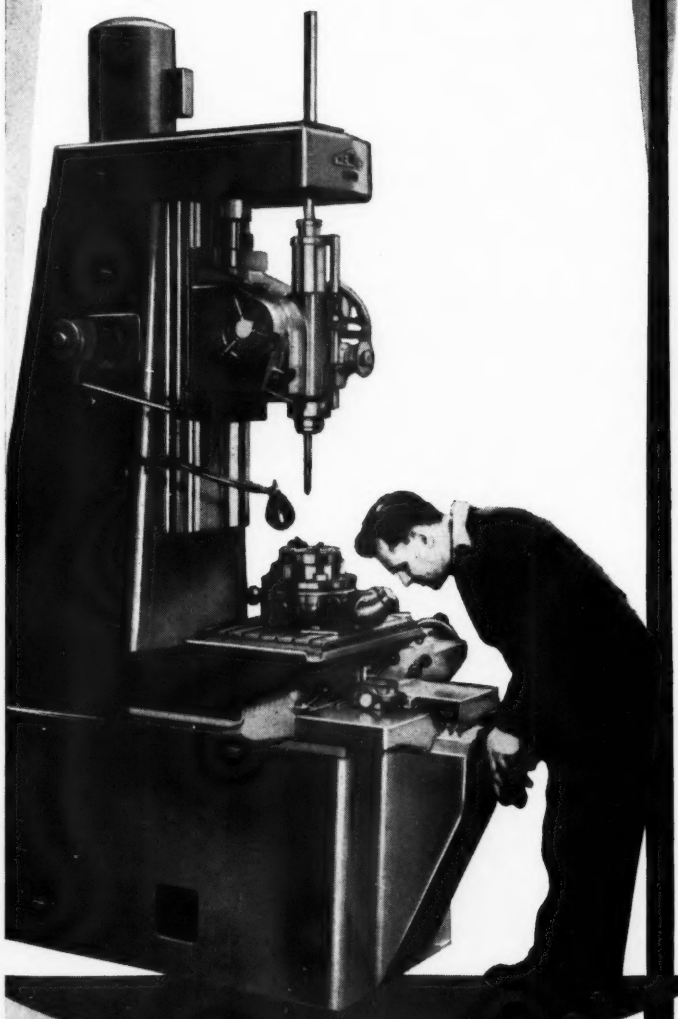

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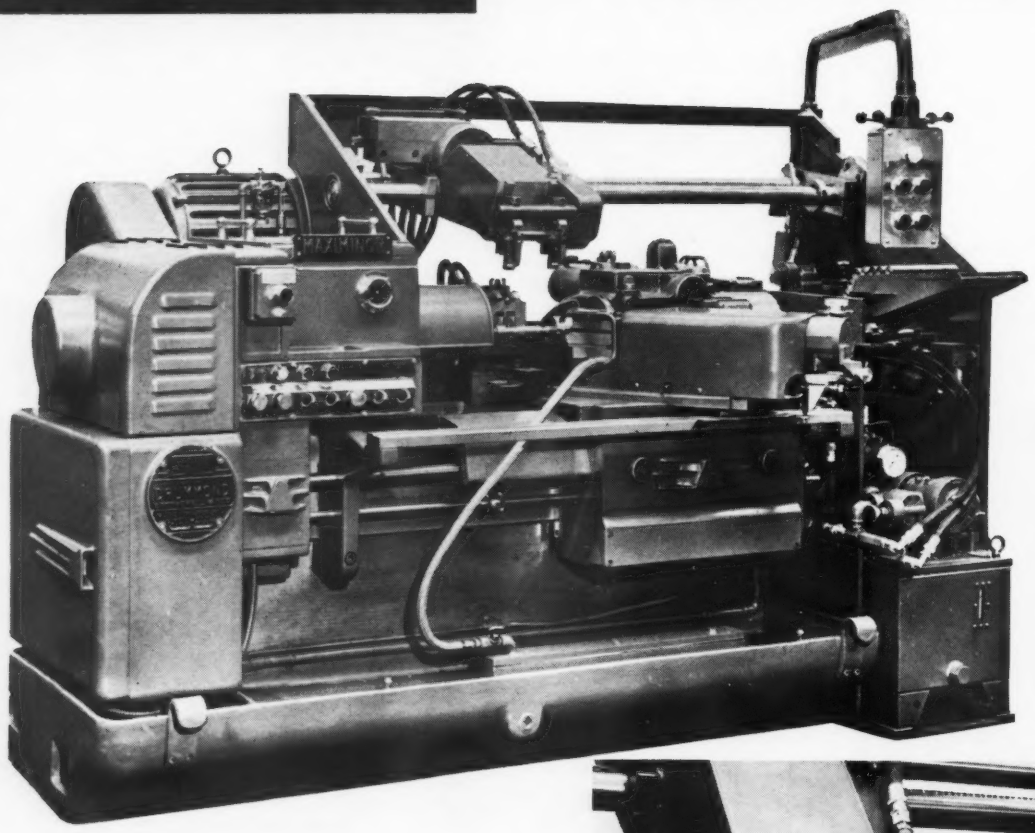

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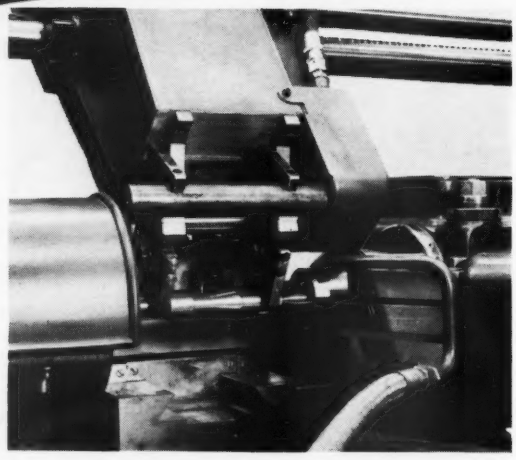

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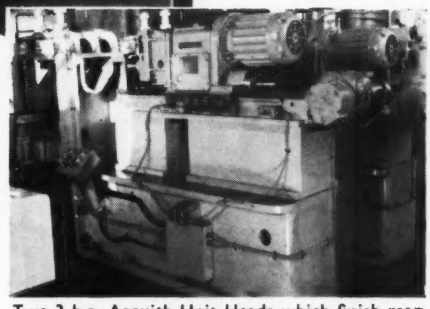
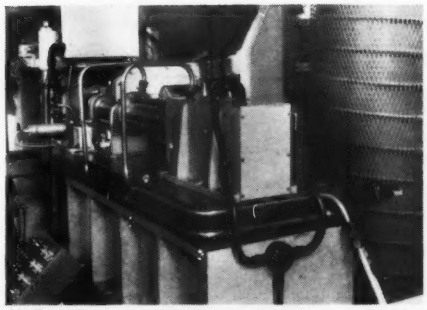


Two 3 h.p. Asquith Unit Heads which finish ream the crankshaft and camshaft bores.



Hydraulically operated pressing station for inserting liner bushes.

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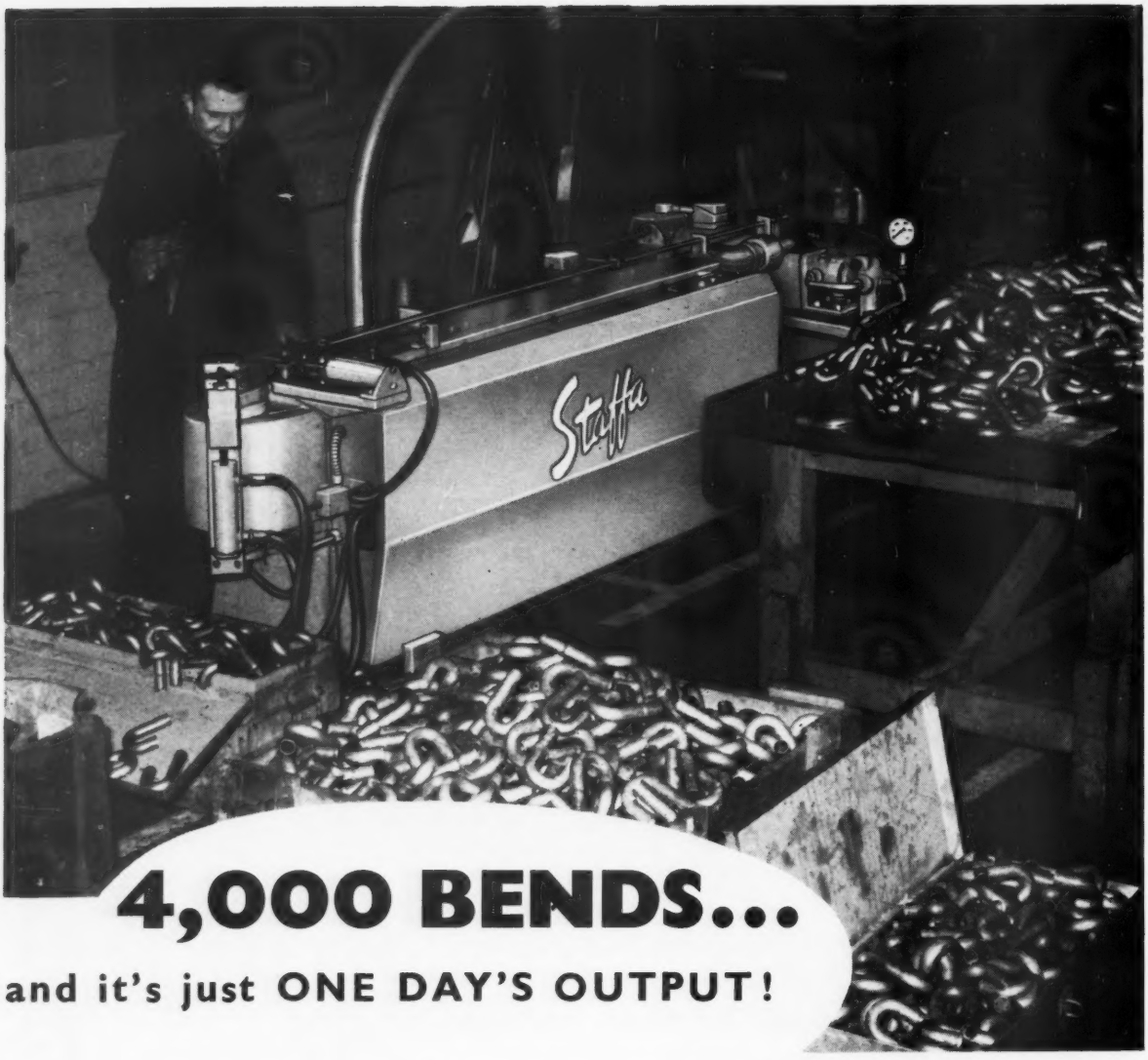

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and it's just ONE DAY'S OUTPUT!

Here is a typical example of high production achieved on a "STAFFA" Production Tube Bender. 4,000 of these 1 in. diameter, 16 s.w.g. copper tubes were bent in a day, a jointed mandrel being employed. If your production calls for large quantities of tube to a similar specification for the bend it is worth while investigating the application of a STAFFA Hydraulic Tube Bending Machine. Why not send details of your bending jobs for a preliminary study?

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5 weeks between regrinds!

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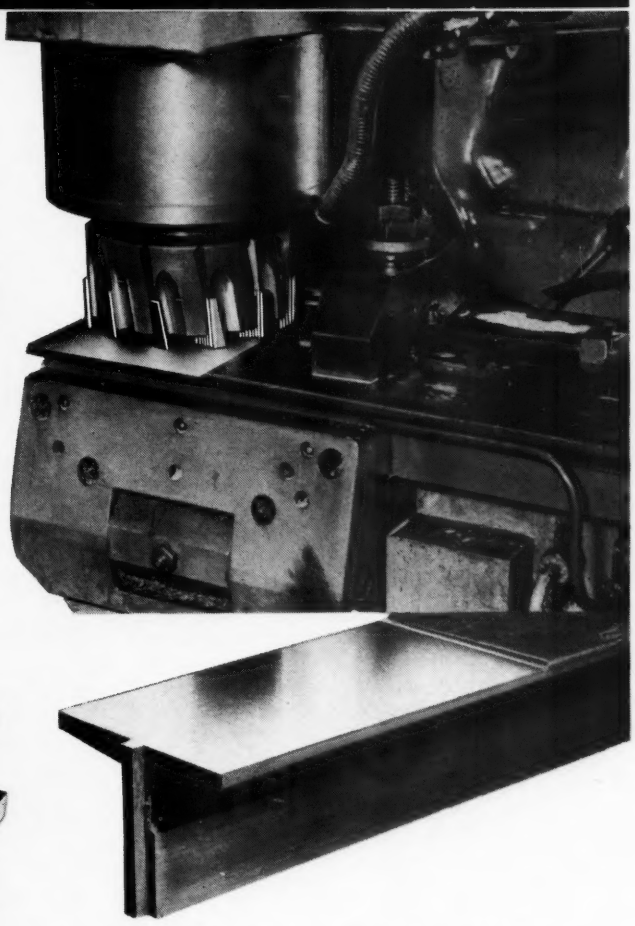

This " Galtona-OK " Serrated Blade High Rake Cutter, 6½ in. diameter, with twelve blades in T.15 high speed steel, has set up a fine record of performance on the milling of fish plate pads on passenger lift guide rails. Speed is 160 r.p.m. (272 f.p.m.), with a feed of 8 in. per min., and depth of cut ⅛ in. ***" Galtona-OK " serrated blade cutters could show improved performance on your own work. Why not consult our Tool Engineers?***

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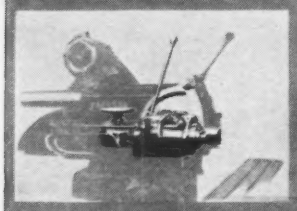
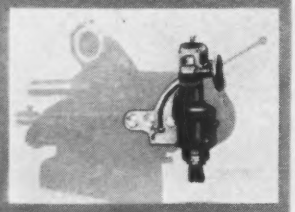
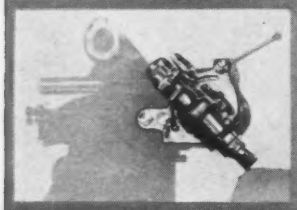
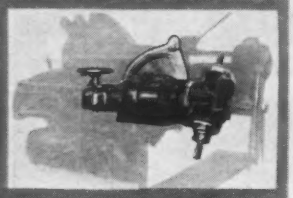
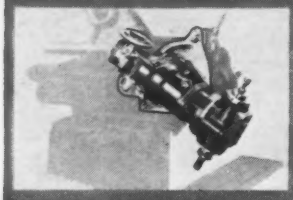
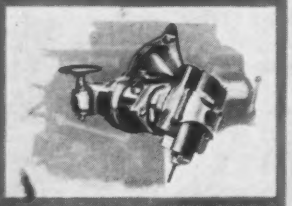

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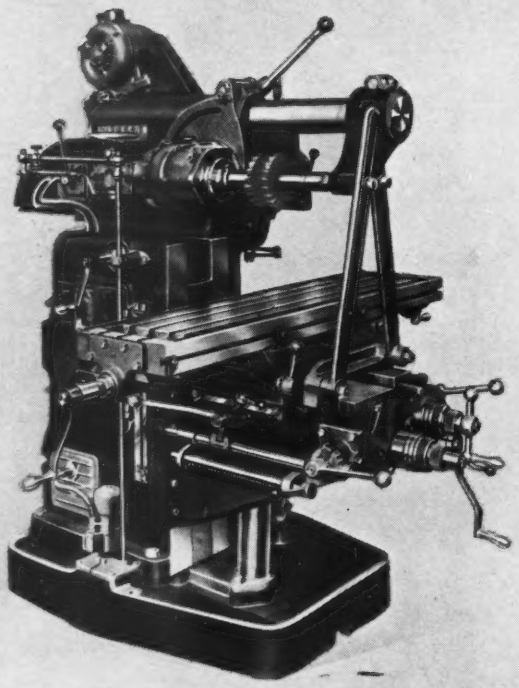
Plus ANGLE
= ADAPTA MILLING



ADAPTA

The ADAPTA Miller (Model N) illustrated above combines in one machine the advantages of horizontal and vertical mills, while at the same time giving facilities for unusual angle cutting. It is ideal for special tool and die work patterns, moulds, etc., as well as for ordinary batch production.

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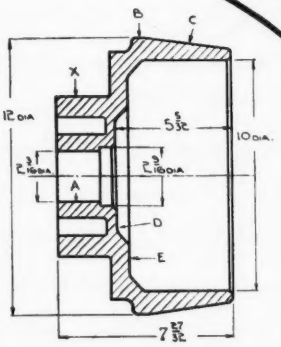
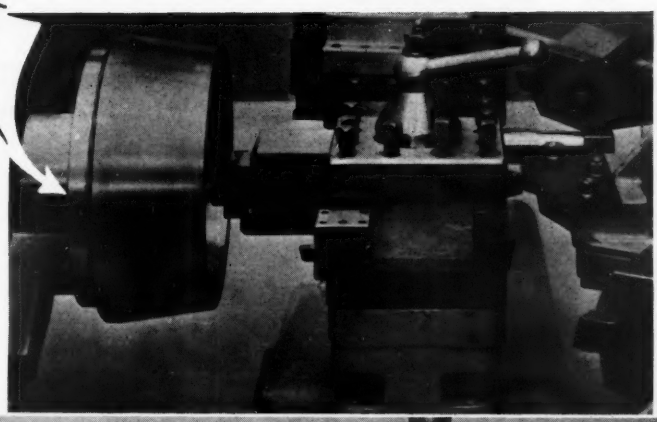
P333A

Maximum Production Special Tool Layouts

CLUTCH

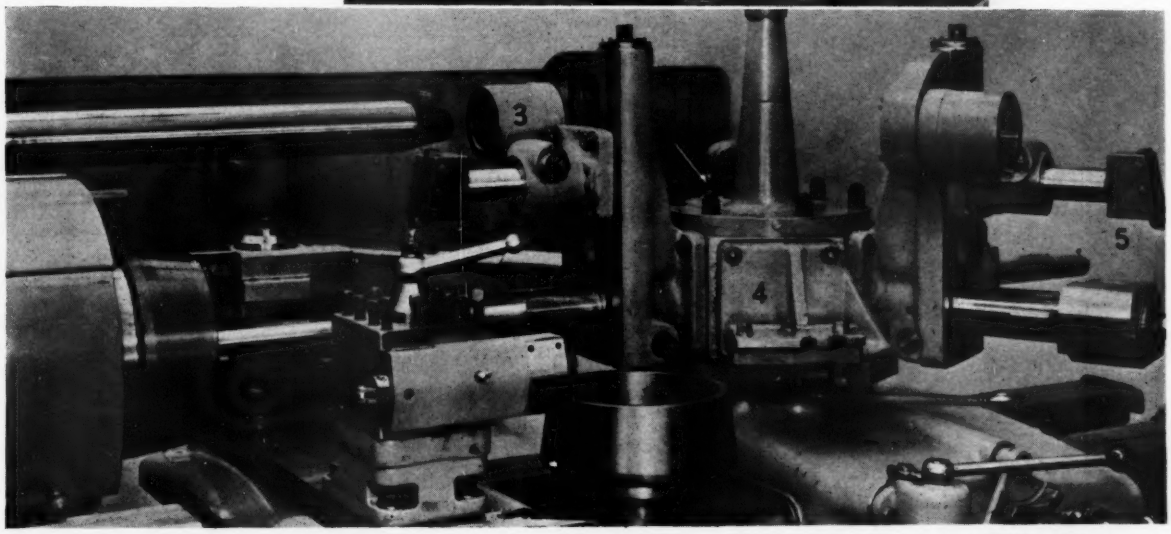




CAST IRON CASTING
Brinell No. 220/228

Floor-to-Floor Time:
17½ mins. each.

Tungsten Carbide Cutting Tools



DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Chuck on X (using Loading Attachment)	1	—	—	—	Hand
2. Rough Bore A & 2 9/16" dia. and Chamfer	2	—	375	260	64
3. Face (2 Cuts)	—	Front 1	93	278	64
4. Rough Bore 10" dia. Rough Knee Turn B and Rough Taper Turn C	3	Rear	75	240	44
5. Contour Face D & E (Rough & Finish)	4	Front 3	93/125	242/325	64
6. Finish Bore 10" Finish Knee Turn B and Finish Taper Turn C and Chamfer 10" dia.	5	Rear	125	390	64
7. Chamfer Outside Dias.	—	Front 2	125	390	Hand
8. Finish Microbore 2 3/16" dia.	6	—	580	333	88
9. Remove (using Attachment)	1	—	—	—	Hand

Ward

No. 10 TURRET LATHE

FITTED WITH 18in TUDOR 3-JAW CHUCK

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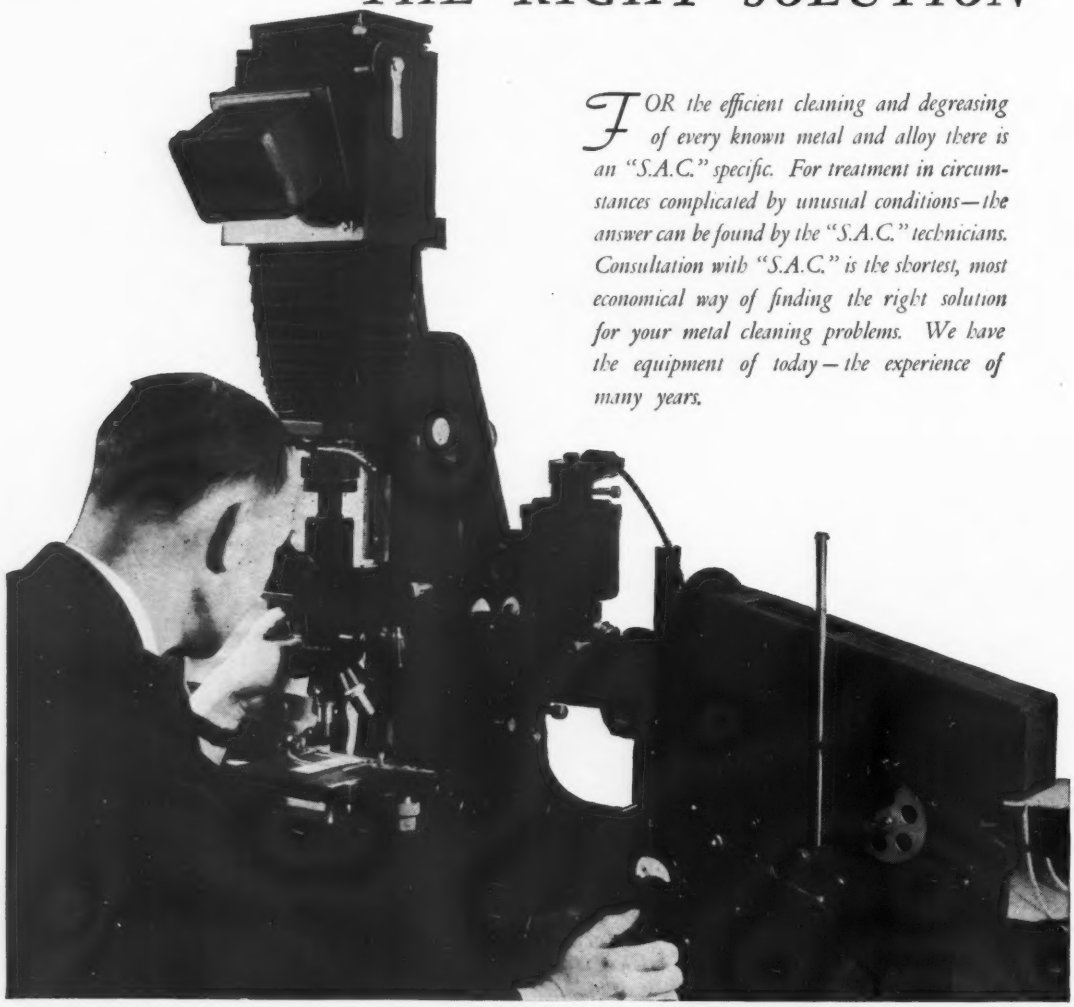

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Araldite is a registered trade name

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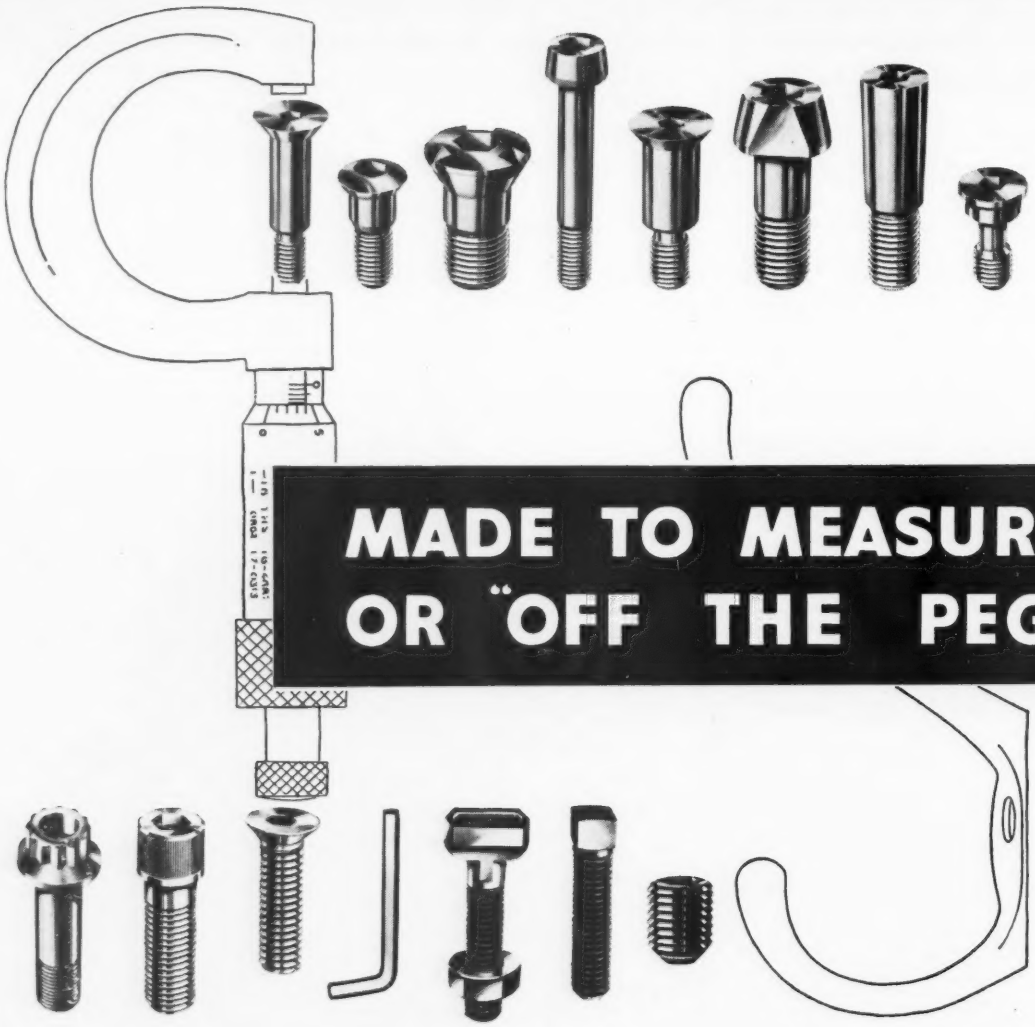

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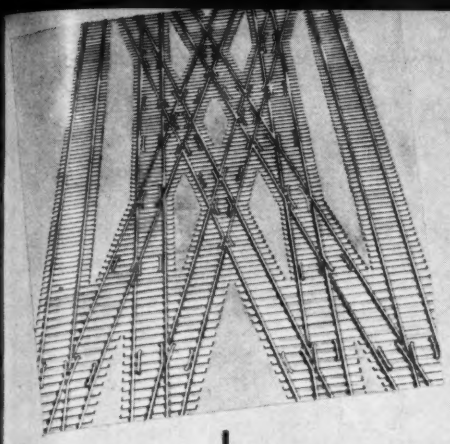

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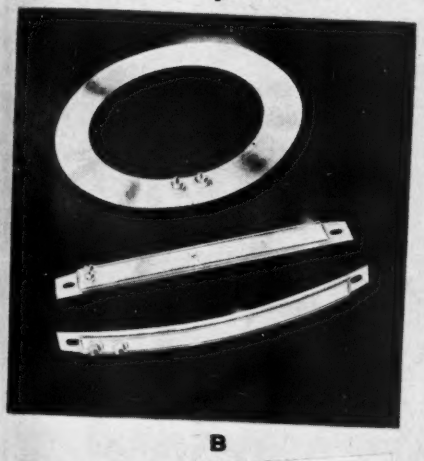

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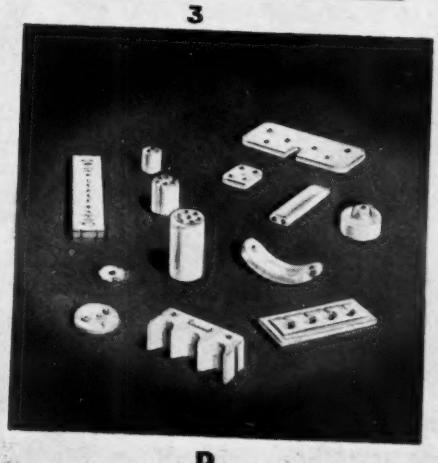

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1 The 3.34 down should have been in this picture. It wasn't late—but the weather was so cc that the artist wouldn't wait for it to arrive. Yet there isn't a speck of ice on the poin

2 It goes like clockwork—and so it should. It takes quite an intricate clockwork mechanis to keep these dials a-turning.

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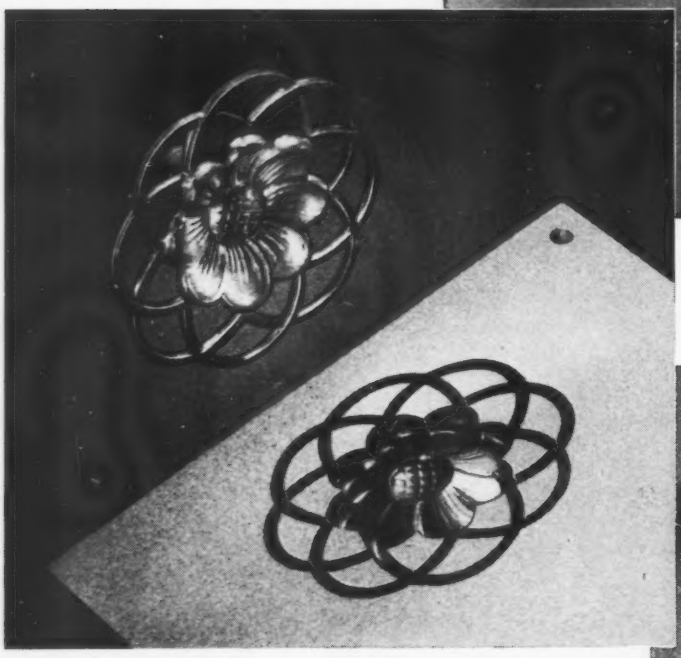

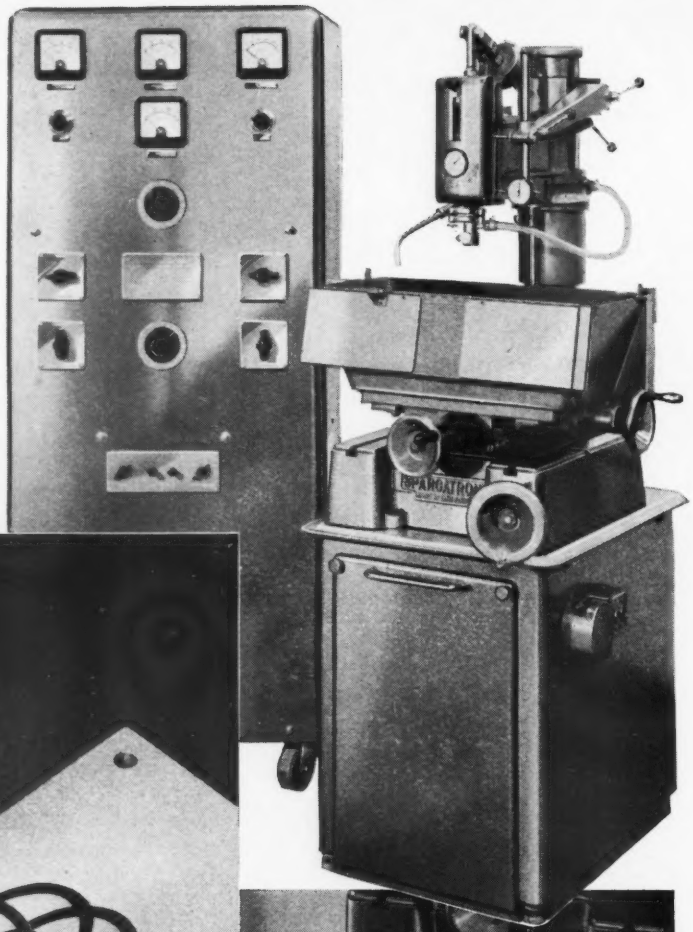

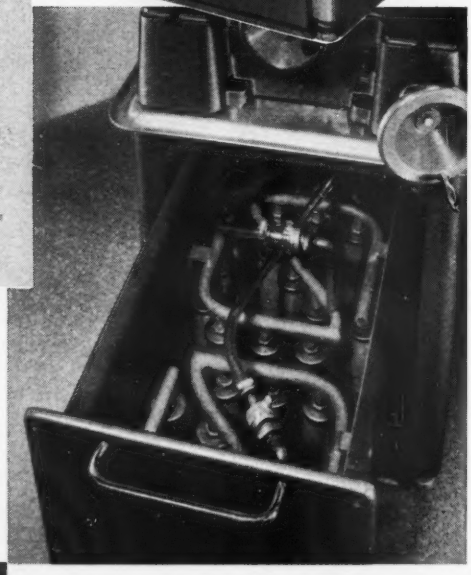

(*Above*) An intricate electrode (Mazak) and finished workpiece (high carbon steel). (*Top Right*) the machine and power unit. Note the extra-large worktank. (*Right*) new filtering system to ensure clean dielectric.

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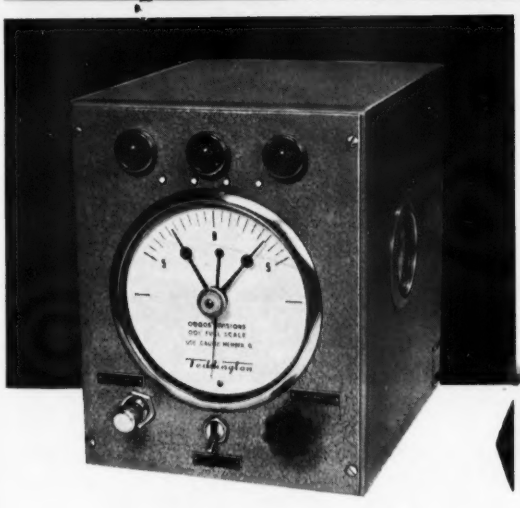

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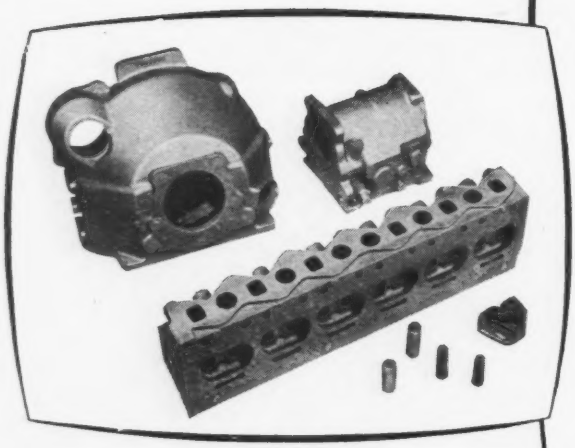

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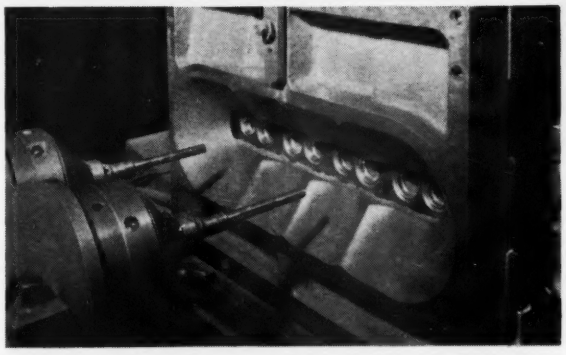

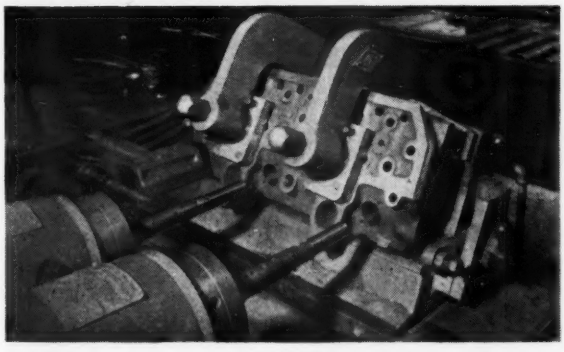

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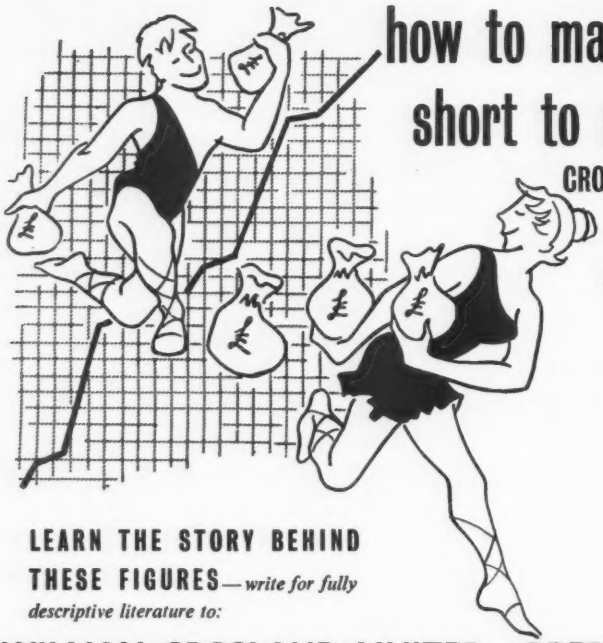

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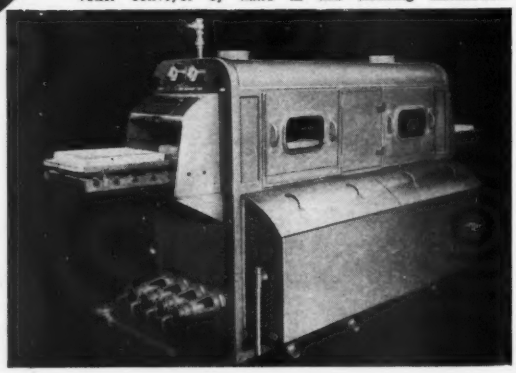

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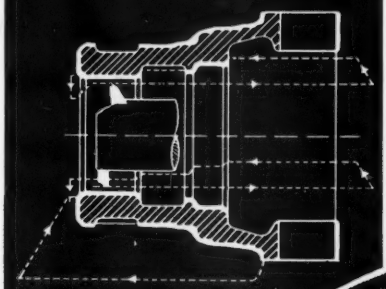

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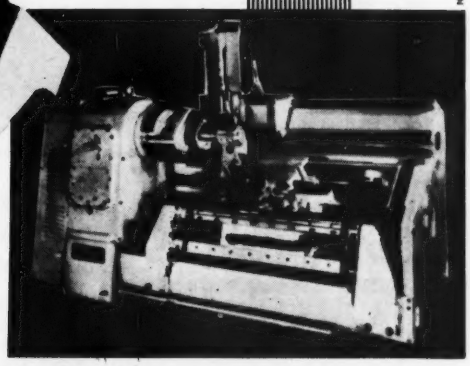

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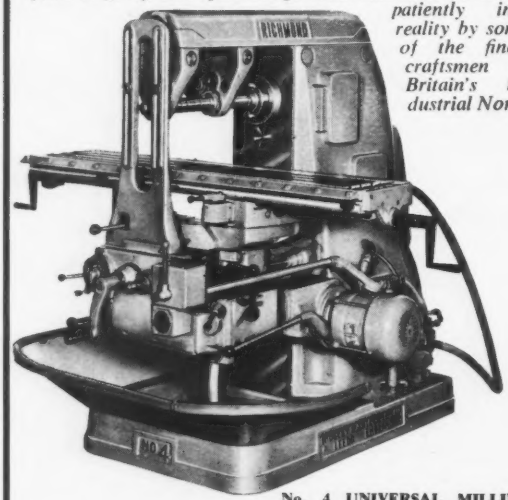

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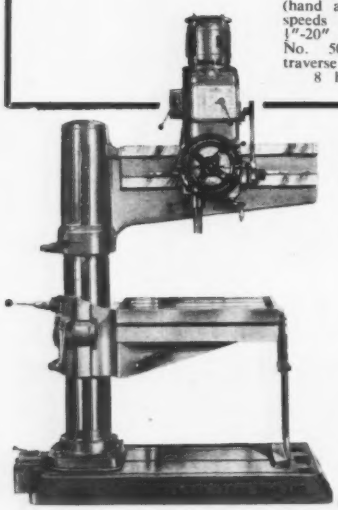

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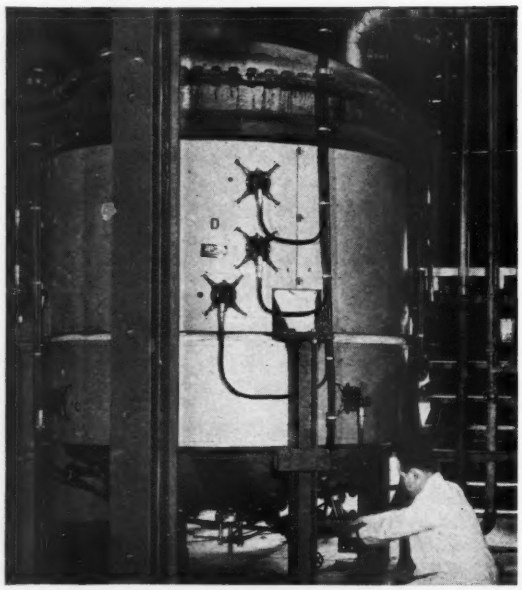

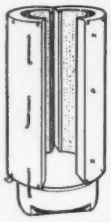

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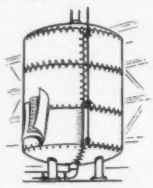

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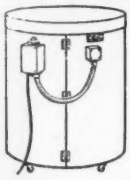

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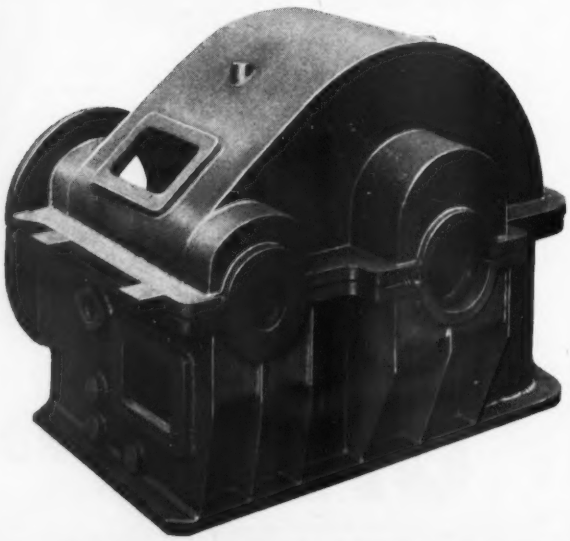

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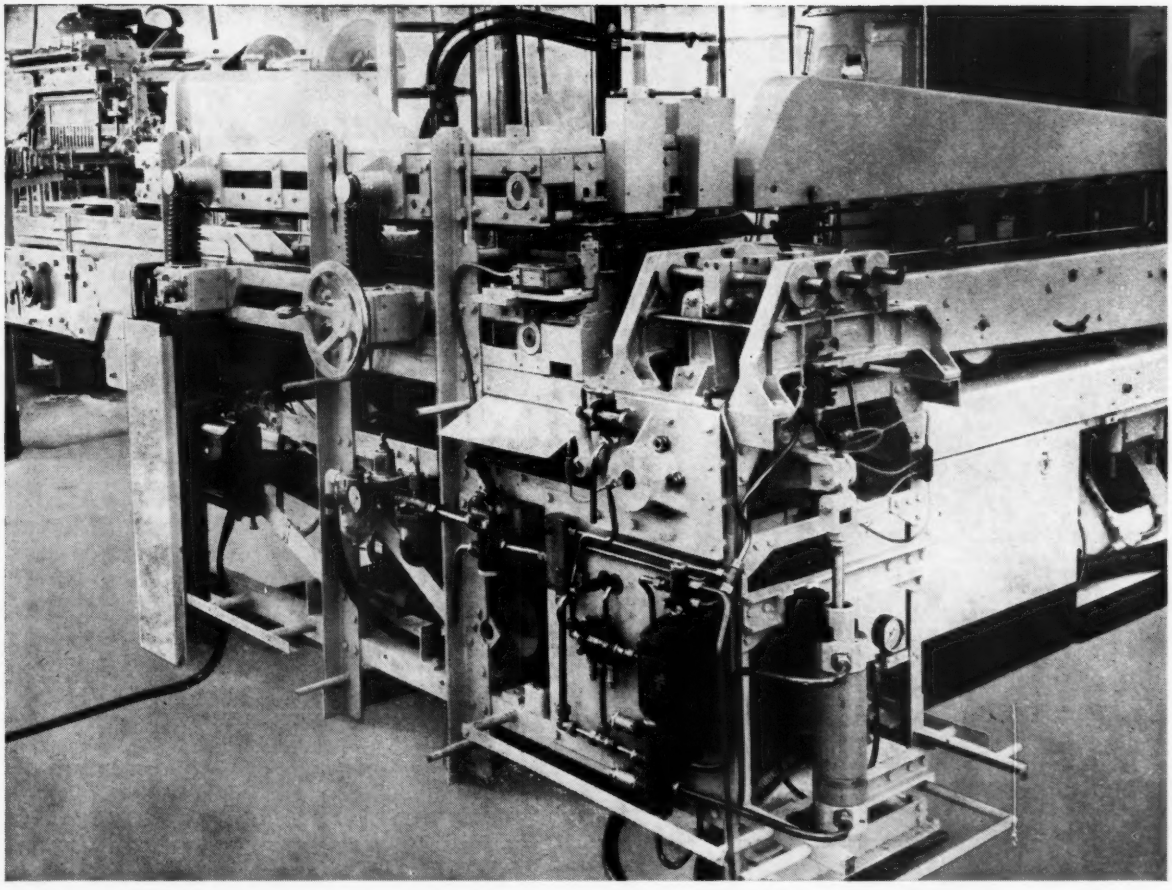

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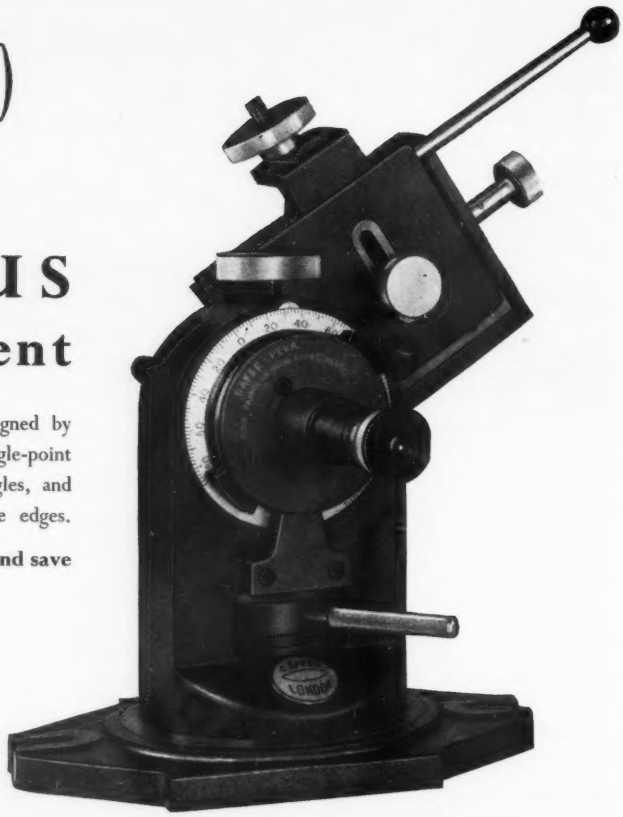

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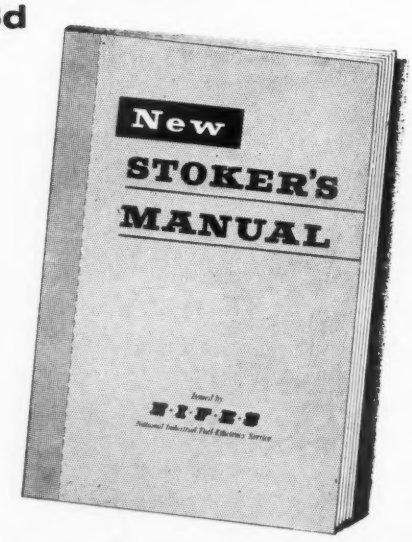

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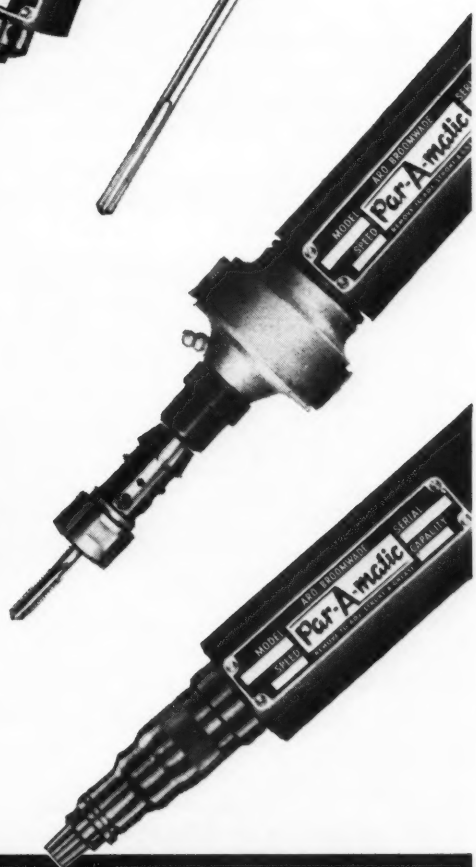

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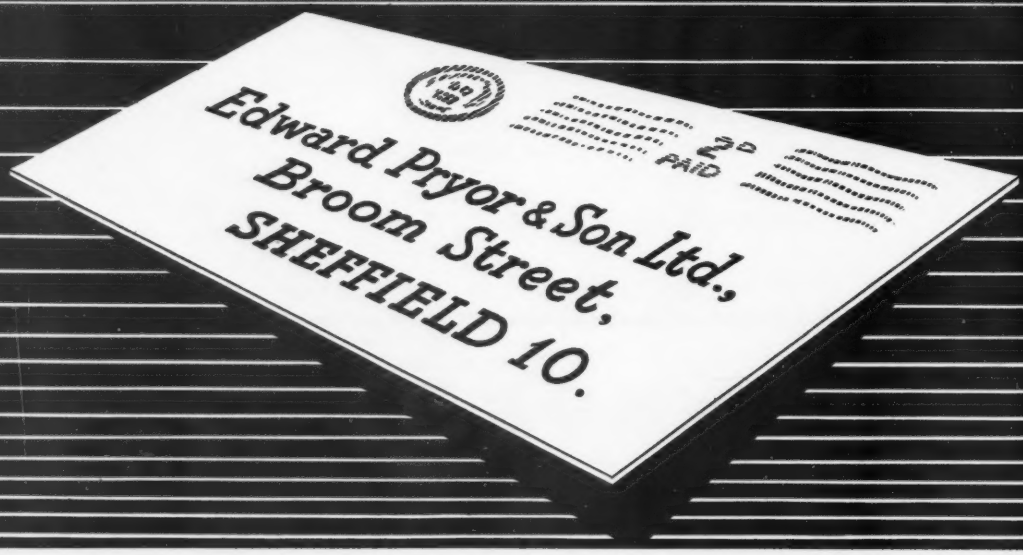

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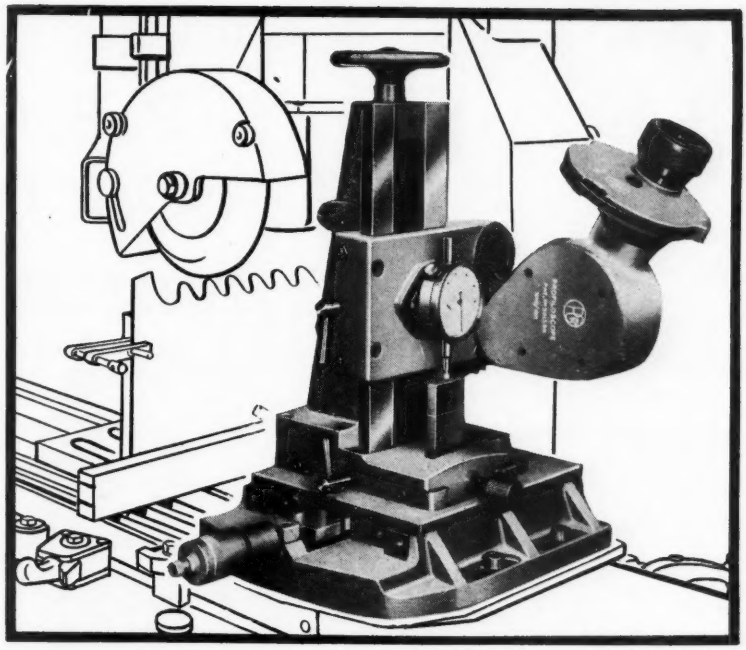

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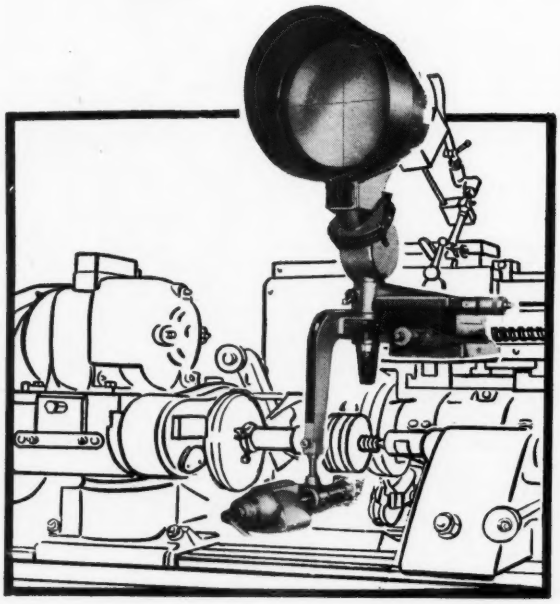

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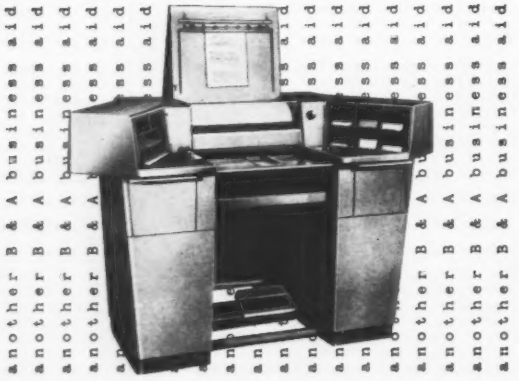

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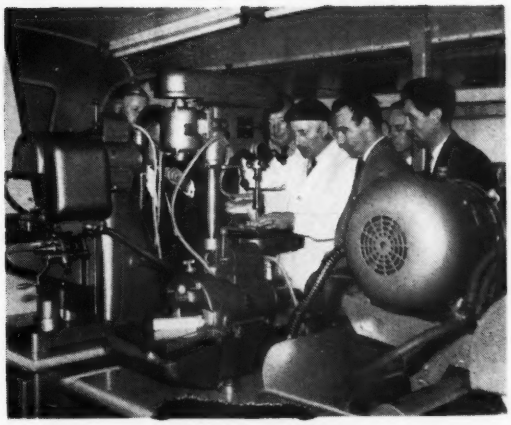

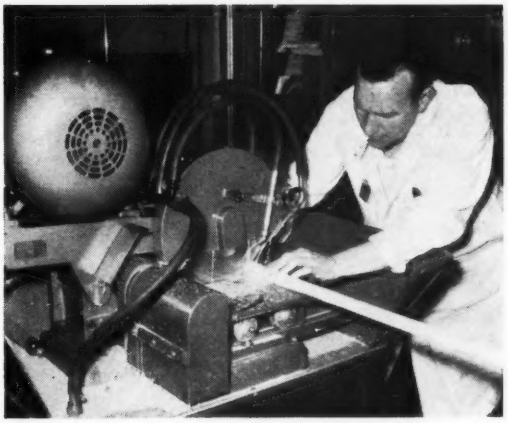

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IDP

BESCO ALL STEEL TREADLE GUILLOTINE

Registered Design No 859515

24 in. wide × 16 S.W.G. mild steel
36 in. wide × 16 S.W.G. mild steel
48 in. wide × 16 S.W.G. mild steel

These treadle guillotines are specially designed to handle the extreme thickness mentioned . . . a unique effort for treadle guillotines. Great strength is obtained from the all-steel construction; the treadles, beams, frames and gauge arms are virtually unbreakable. Built-in hold-down and adjustable gauges with concealed strip lighting if required, give economical, clean and accurate cutting.

Two wide machines to cut

72 in. wide × 18 S.W.G. mild steel
96 in. wide × 20 S.W.G. mild steel

complete this versatile range of treadle guillotines.

The 36 in. and 48 in. × 16 S.W.G. machines can be supplied for motor drive.

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Wadkin Router

CUTS OVER-ALL MACHINING TIME BY 80%

on *Sterling* slip flasks

Wadkin Articulated Arm Router L.C. face milling the end plates of the Sterling slip flask shown right. Photographs are reproduced by courtesy of Sterling Foundry Specialties Ltd., Bedford.

Here is yet another example of how the latest Wadkin High Speed Routers completely outdate all previous methods of machining light alloys. Since installing a Wadkin Articulated Arm Router L.C., Sterling Foundry Specialties Ltd., have drastically reduced production times on their aluminium slip flasks. All the face milling operations, including the milling of inside faces to an angle of 4°, are accurately machined in a fraction of the time previously taken, and no further finishing operation is required. Why not let us prove the amazing output capabilities of this machine — preferably by a demonstration on your own jobs. Meanwhile, write for a copy of leaflet No. 831 which describes the machine and its applications.

Wadkin

Wadkin Ltd., Green Lane Works, Leicester. Tel.: 68151 (7 lines) London Office : 62-64 Brook Street, W.1. Tel.: MAYfair 7048

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The trend towards higher speeds in modern engineering makes dynamic balancing an all-important factor right from the drawing board, in every field where fans, electric rotors, crankshafts, turbines, universal shafts or other rotating parts are used. The static workpiece which seems so harmless becomes a difficult, even dangerous unit when in motion. As speed increases, oscillation — inducing centrifugal forces develop because the dynamic forces rise as the square of the speed. Centrifugal force soon exceeds the dead weight of the rotor.

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AVERY for **ELECTRODYNAMIC BALANCING**

W. & T. Avery, Limited, Soho Foundry, Birmingham 40

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PM143

FOR miniature ELECTRONIC PARTS

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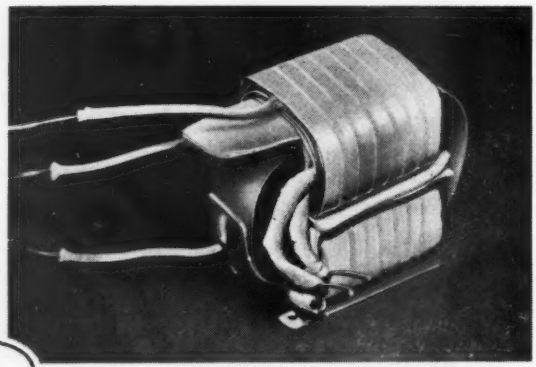
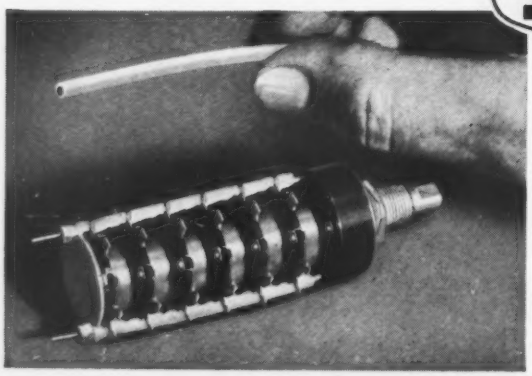
With increased emphasis on the miniaturization of electronic systems, Fluorocarbon *TFE* tape and thin wall sleeving are being subjected to more severe requirements than ever before. Uniform density and controlled properties in thin-walled sections are of major importance. That's why POLYPENCO Fluorocarbon *TF* is being used so widely in the electronics field today. Polypenco's rigid in-process testing assures you unvarying quality . . . the quality necessary to design and fabricate more minute parts and components for top performance.



Aircraft high voltage pulse transformer uses POLYPENCO Fluorocarbon *TFE* Tape insulation for interlayer case lining and terminal wrapper.

POLYPENCO

POLYPENCO Fluorocarbon *TFE* Thin Wall Sleeving used in miniature rotary tap switch combines high dielectric strength in thin sections with resistance to soldering heats.



FLUOROCARBON *TFE* Outstanding Properties

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- Power Factor 0.0005
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- Surface Resistivity 100% R.H. 10^{13} ohm
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AS YOU DO TEMPERATURE

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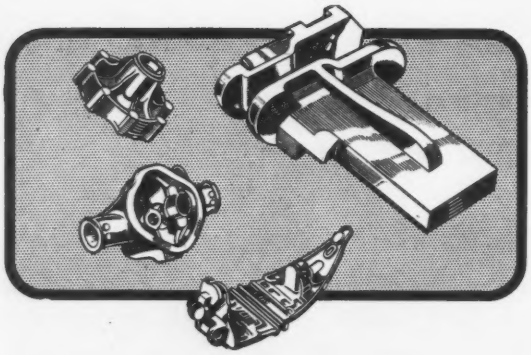

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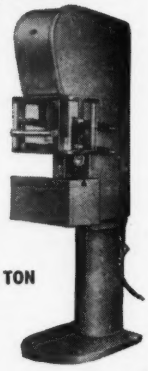

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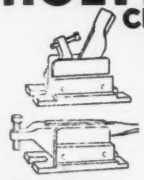

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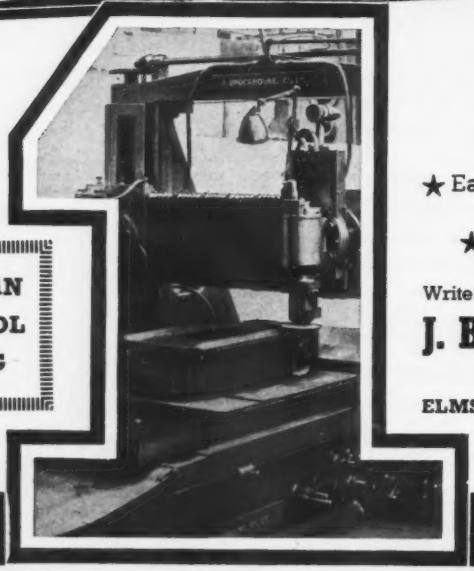

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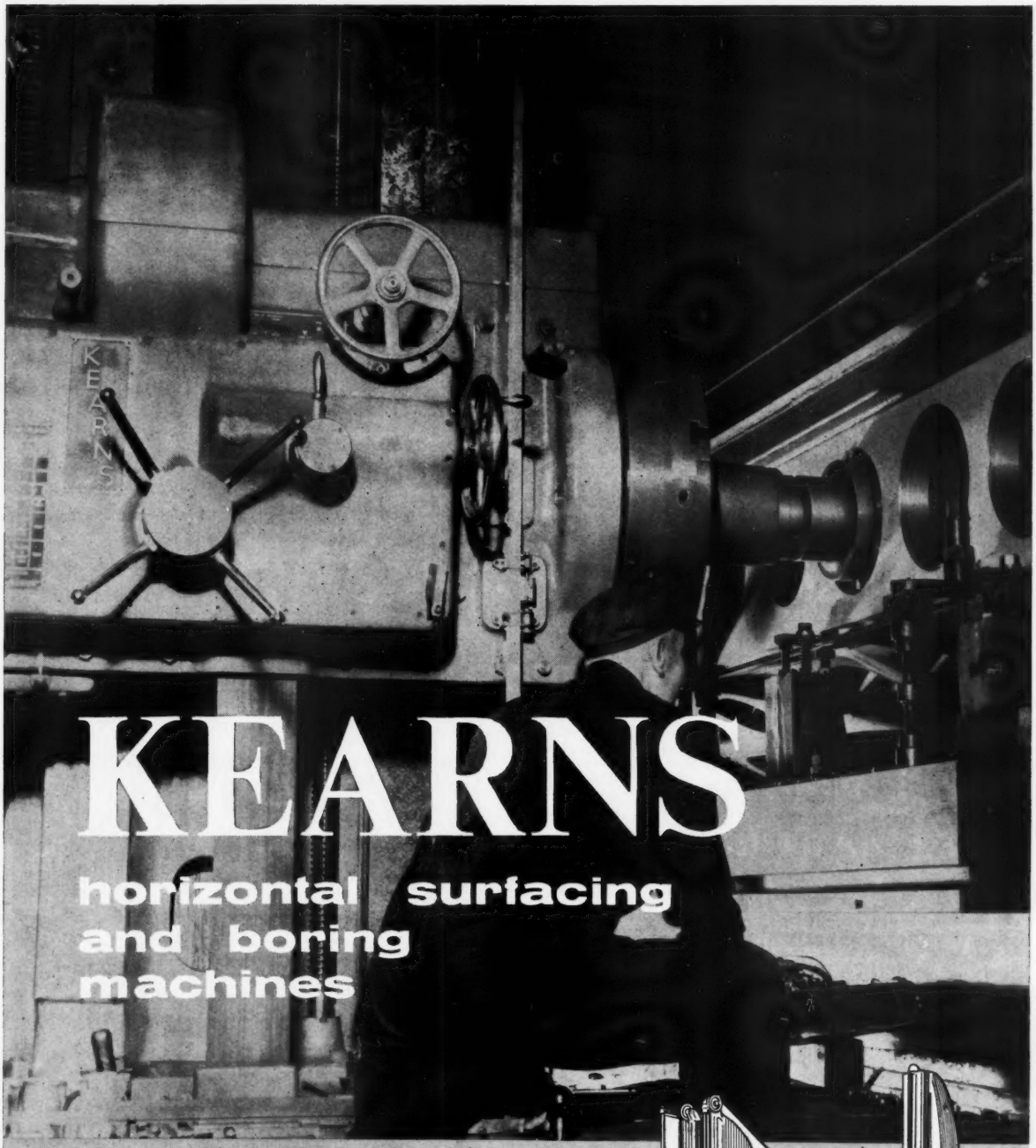

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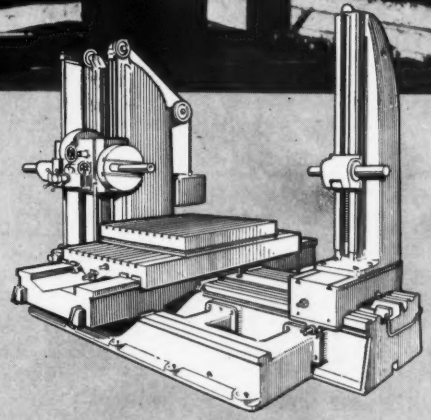

No. 5 Kearns Patent wide bed horizontal borer machining the top face of a Paxman 16 cylinder YL engine. (courtesy Davey, Paxman & Co. Ltd.)

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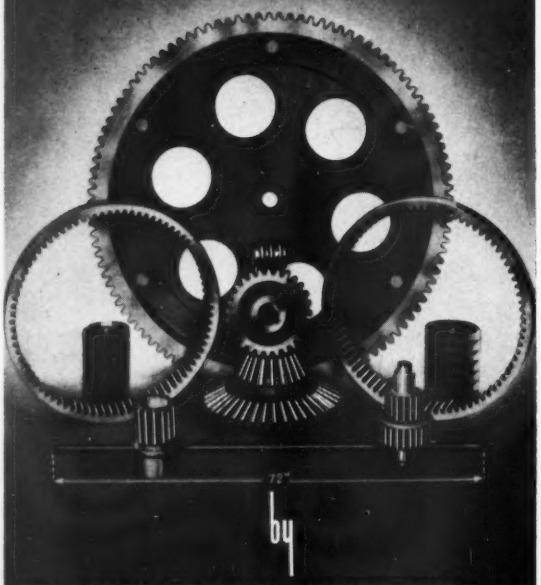

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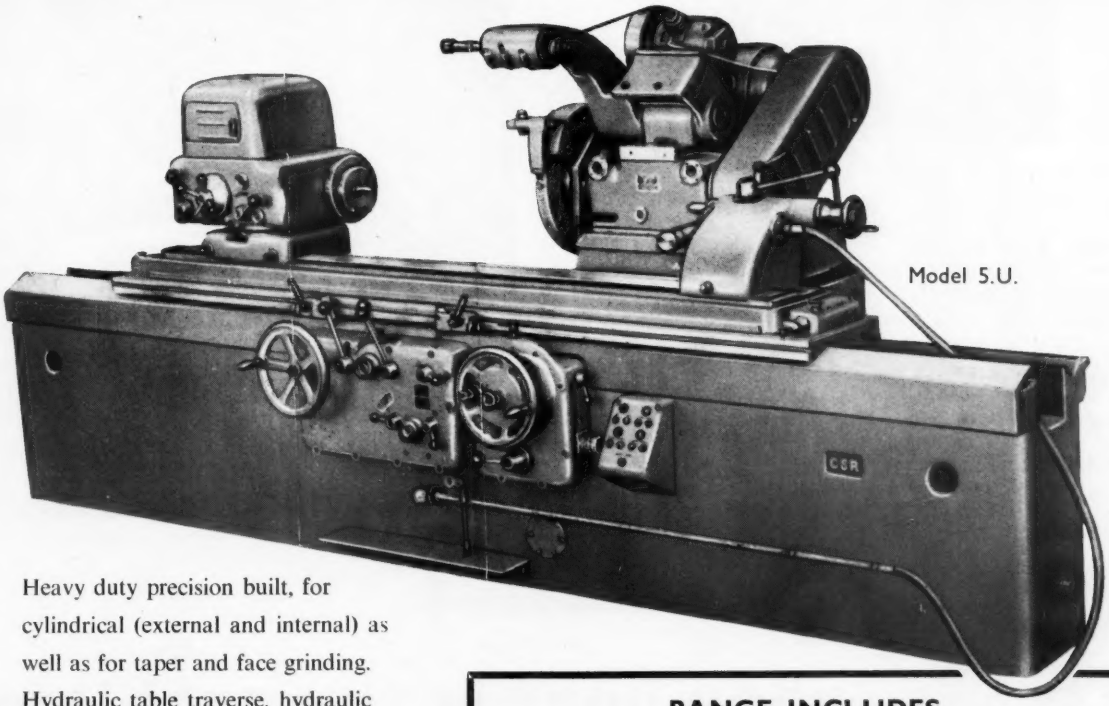

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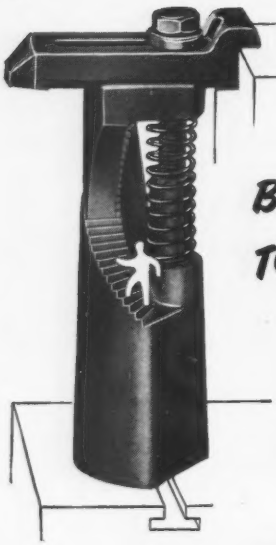

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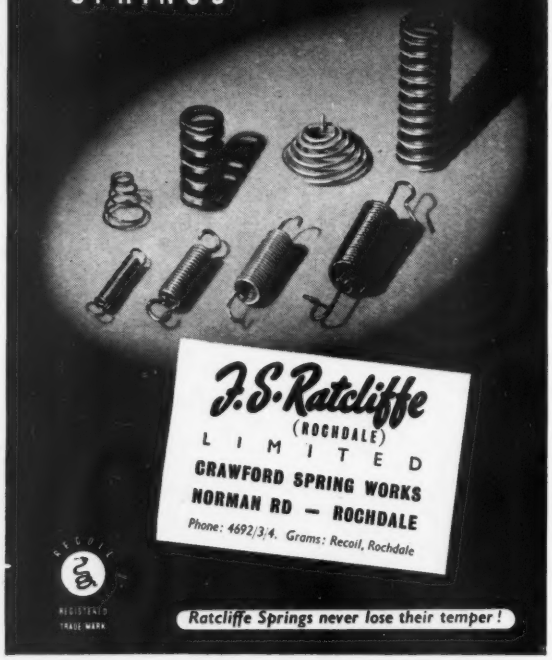

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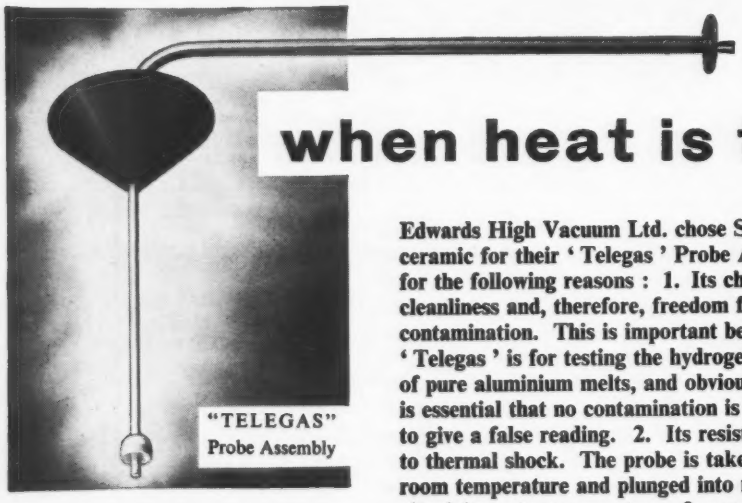

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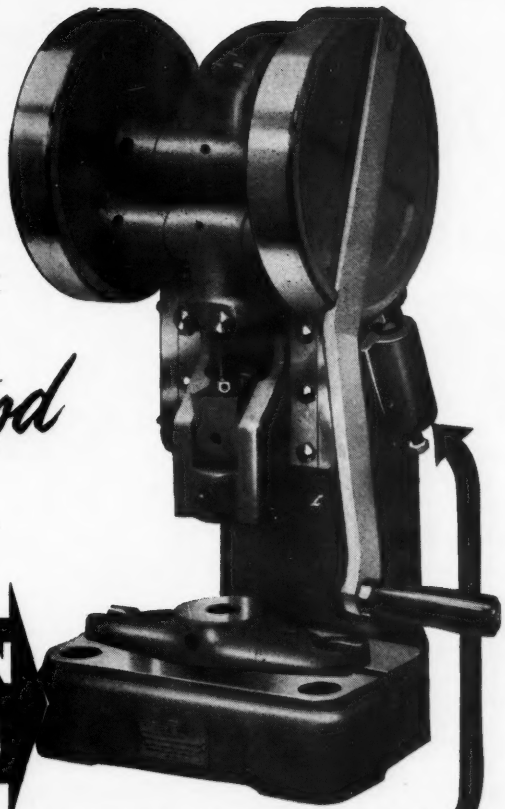

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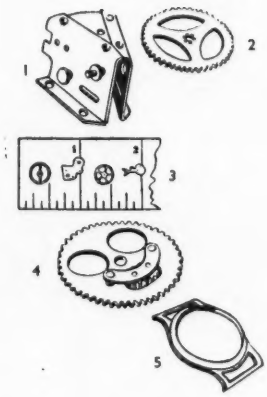

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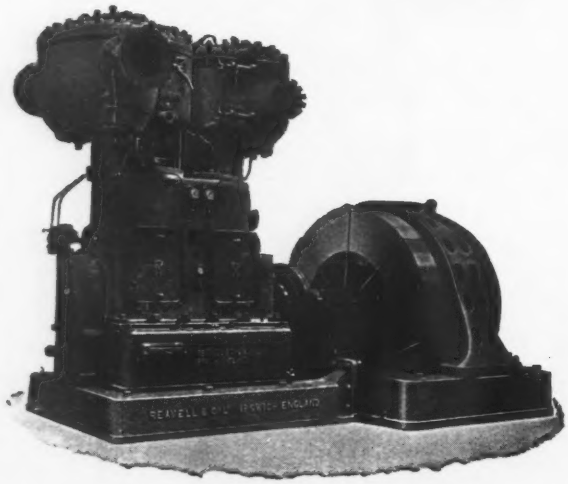

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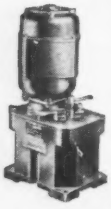

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JACKS

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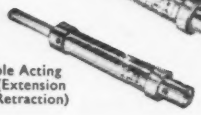

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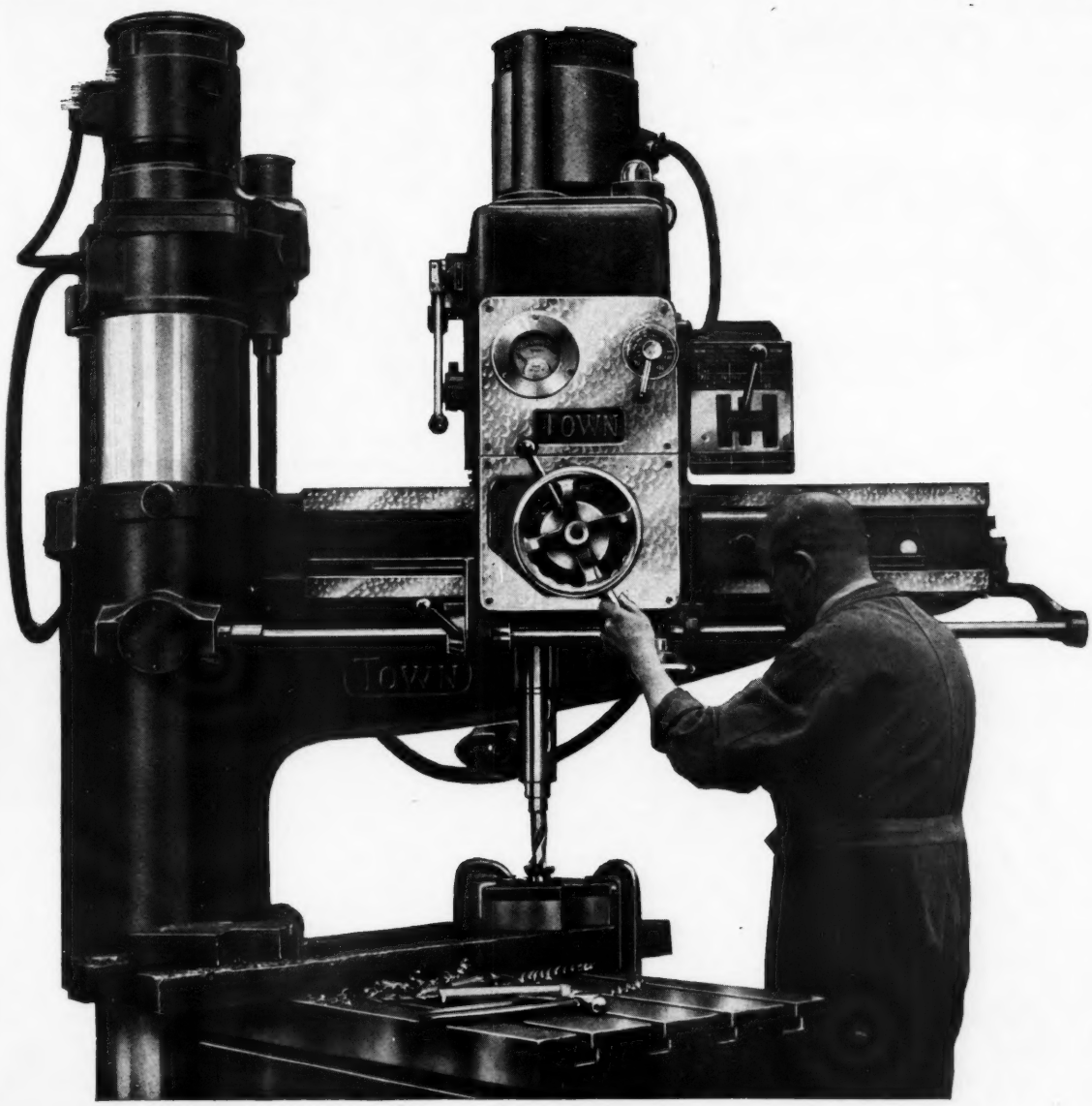

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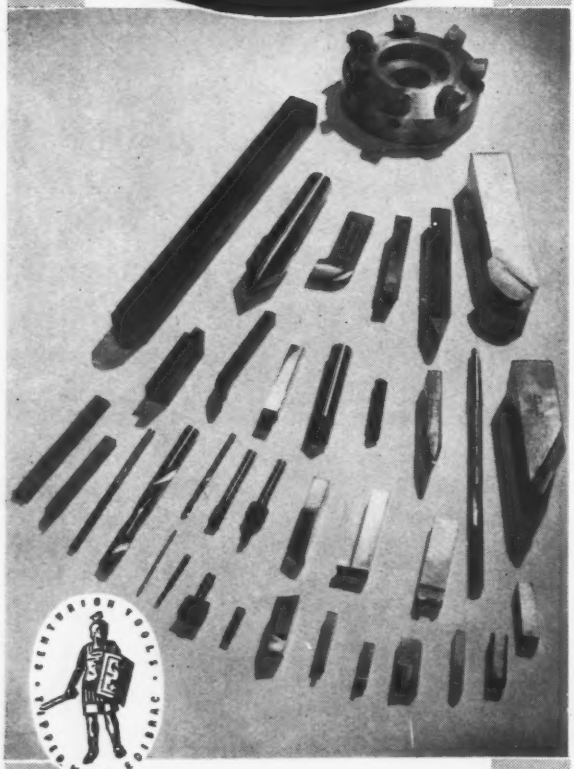

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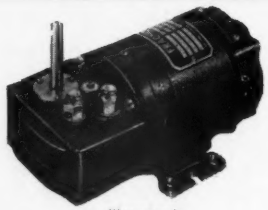

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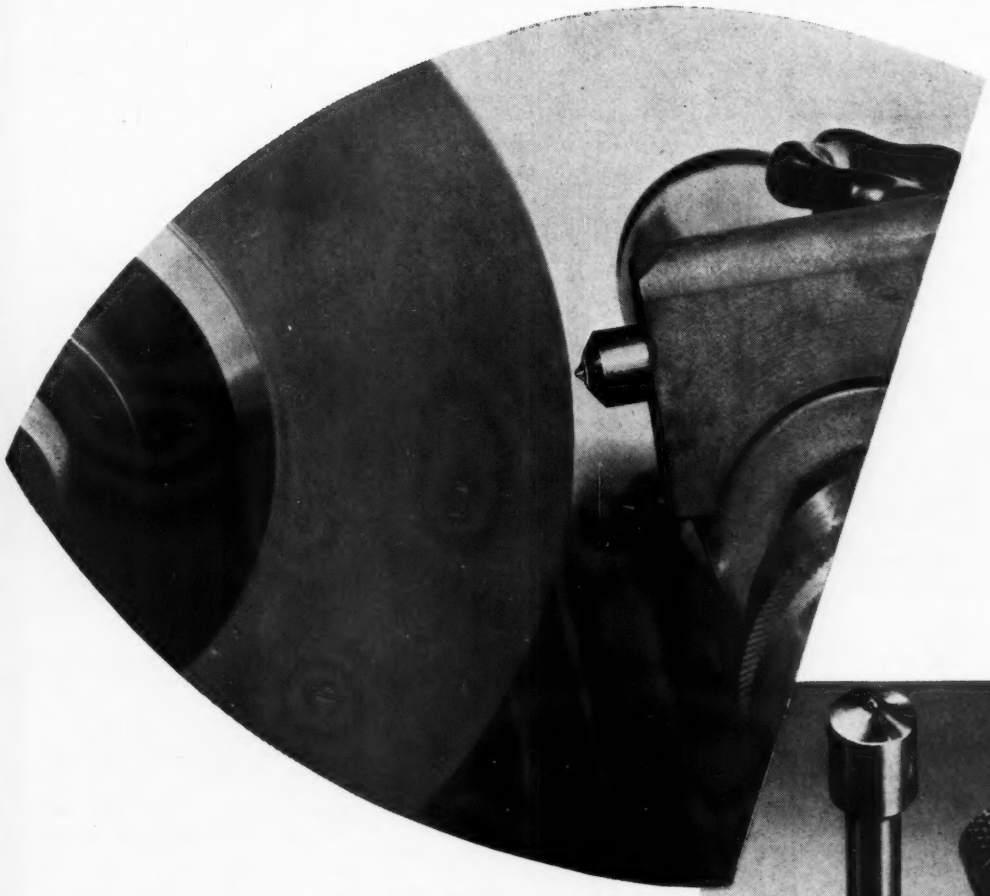

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INDEX TO ADVERTISEMENTS

Please note that all advertisement pages are prefixed with the letter "A".

	Page
Acru Electric Tool Manufacturing Co. Ltd., The	—
Adcock & Shipley, Ltd.	A6
Ajax Machine Tool Co. Ltd.	—
Allen, Edgar, & Co. Ltd.	A20
Allspeeds, Ltd.	A23
Aluminium Wire & Cable Co. Ltd.	—
Archdale, James, & Co. Ltd.	A54
Armstrong Patents Co. Ltd.	—
Arrow Electric Switches, Ltd.	—
Asquith, William, Ltd.	A45
Associated Electrical Industries, Ltd.	—
Automotive Products Co. Ltd.	—
Avery, W. & T., Ltd.	A79
B.S.A. Tools, Ltd.	A16
Baker, C., Instruments, Ltd.	A72
Baldwin Instrument Co. Ltd.	—
Barber & Colman, Ltd.	—
Barraclough, R. W., Ltd.	—
Benton & Stone, Ltd.	A12
Birlec-Efco (Melting), Ltd.	—
Birlec, Ltd.	—
Birmingham Aluminium Casting (1903) Co. Ltd.	—
Birmingham Tool & Gauge Co. Ltd.	A4
Bliss, E. W. (England), Ltd.	—
Block & Anderson, Ltd.	A76
Bolton Railway Wagon & Ironworks Co. Ltd.	A38
Bratby & Hinchliffe, Ltd.	A66
Bray, Geo., & Co. Ltd.	A57
British Aero Components, Ltd.	—
British Bellows, Ltd.	—
British Die Casting & Engineering Co. Ltd.	A2
British Thomson-Houston Co. Ltd.	—
British Timken, Ltd.	—
Brockhouse, J., & Co. Ltd.	A82
Broom & Wade, Ltd.	A73
Brown, David, Corpn. (Sales), Ltd., The	A62
Buck & Hickman, Ltd.	A31
Burton Griffiths & Co. Ltd.	A16
Butler Machine Tool Co. Ltd., The	—
Butterley Co. Ltd., The	—
Carborundum Co. Ltd.	—
Churchill Machine Tool Co. Ltd.	—
Churchill-Redman, Ltd.	—
Ciba (A.R.L.), Ltd.	A51
Cincinnati Milling Machines, Ltd.	A18
Clarkson (Engineers), Ltd.	—
Cohen, Geo., Sons, & Co. Ltd.	—
Concentric Manufacturing Co. Ltd.	—
Cooper & Co. (B'ham), Ltd.	—
Coventry Climax Engines, Ltd.	*Outside Back Cover*
Coventry Gauge & Tool Co. Ltd.	—
Cow, P. B., & Co. Ltd.	A76
Crawford Collets, Ltd.	—
Crofts (Engineers), Ltd.	—
Crompton Parkinson (Stud Welding), Ltd.	—
Crosland, William, Ltd.	A66
Davis, Stuart, Ltd.	—
Dawe Instruments, Ltd.	—
Dawson Bros., Ltd.	—
Dean Smith & Grace, Ltd.	A34
Delapena & Son, Ltd.	A14
Denhams Engineering Co. Ltd.	—
Dowding & Doll, Ltd.	A30
Drummond Asquith (Sales), Ltd.	A46
Drummond Bros., Ltd.	A44
E.N.V. Engineering Co. Ltd.	A84
Edibrac, Ltd.	A90
Edwards, F. J., Ltd.	A78
Electrical Development Association	—
Electric Resistance Furnace Co. Ltd.	—
Elliott, B. (Machinery), Ltd.	—
English Electric Co. Ltd., The	—
English Numbering Machines, Ltd.	—
English Steel Tool Corpn., Ltd.	—
Exors of James Mills, Ltd.	A26
Firth, Thos., & Brown, John, Ltd.	—
Flame Hardeners, Ltd.	—
Fletcher Miller, Ltd.	A60
Ford Motor Co. Ltd.	A59
Fractional H.P. Motors, Ltd.	A90
G.P.A. Tools & Gauges, Ltd.	—
Gas Council, The	A36, A37
Gear Grinding Co. Ltd.	A35
Glostics, Ltd.	A69
Goulder, J., & Sons, Ltd.	A64
Guest, Keen & Nettlefolds (Midlands), Ltd.	—
Hale & Hale (Tipton), Ltd.	A82
Harris, John, Tools, Ltd.	—
Harrison, T. S., & Sons, Ltd.	—
Heenan & Froude, Ltd.	A65
Herbert, Alfred, Ltd.	A11
High Speed Service Tool Co. Ltd.	—
Hilger & Watts, Ltd.	—
Holt, James (Engineers), Ltd.	A82
Horstmann Gear Co. Ltd., The	—
Hunt, Herbert, & Sons, Ltd.	A70
Hurst, M. H. (Engineering), Ltd.	—
Hydraulics & Pneumatics, Ltd.	A84
Hymatic Engineering Co. Ltd., The	A10
I.C.I., Ltd.	A15
Ilford, Ltd.	A56
Impregnated Diamond Products Ltd.	A77
Ingham, Robert, Clark & Co.	A42
Integra, Leeds & Northrup, Ltd.	A81
International Computers and Tabulators	—
Isopad, Ltd.	A68
Jones, E. H. (Machine Tools), Ltd.	A27
Kearns, H. W., & Co. Ltd.	A83
Keelavite Hydraulics, Ltd.	A9
King, Geo. W., Ltd.	A53
Kingsbury, Geo., & Co. (Machine Tools), Ltd.	—
Landis Lund, Ltd.	A63
Lang, John, & Sons, Ltd.	—
Lang Pneumatic, Ltd.	A32
Lapointe Machine Tool Co. Ltd.	—
Ley's Malleable Castings Co. Ltd.	—
Lincoln Electric Co. Ltd., The	A19
Lloyd, Richard, Ltd.	A47
Lodge Plugs, Ltd.	A86
London Oil Refining Co. Ltd., The	—
Macready's Metal Co. Ltd.	A38
Marbaix, Gaston E., Ltd.	A21
Markland Scowcroft, Ltd.	A33
Marsden & Shiers, Ltd.	A88
Martonair, Ltd.	—
Maxam Power, Ltd.	A71
Measurement, Ltd.	—
Metropolitan-Vickers Electrical Co. Ltd.	A29
Midgley & Sutcliffe, Ltd.	A68
Mobil Oil Co. Ltd.	A41
Morris, B. O., Ltd.	A55
National Industrial Fuel Efficiency Service	A72
Neill, James, & Co. (Sheffield), Ltd.	A80
Newall, A. P., & Co. Ltd.	A74
Newall Group Sales, Ltd.	A5, A43
Norton Grinding Wheel Co. Ltd.	*Inside Back Cover*
Oliver Pell Control, Ltd.	—
Osborn, Samuel, & Co. Ltd.	—
Park Gate Iron & Steel Co. Ltd.	—
Parkinson, J., & Son (Shipley), Ltd.	A48
Philips Electrical, Ltd.	—
Phosphor Bronze Co. Ltd., The	—
Polypenco, Ltd.	A80
Power Jacks, Ltd.	A88
Precision Grinding, Ltd.	A75
Protolite, Ltd.	A8
Pryor, Edward, & Son, Ltd.	A74
Rack Engineering, Ltd.	—
Ratcliffe, F. S. (Rochdale), Ltd.	A86
Reavell & Co. Ltd.	A88
Reliance Gear & Eng. Co. (Salford), Ltd.	A84
Renold Chains, Ltd.	—
Resilient Grip, Ltd.	A64
Rockwell Machine Tool Co. Ltd.	A17, A86
Rocol, Ltd.	—
Rowland, F. E., & Co. Ltd.	A13
Rubert & Co. Ltd.	—
Russell, S., & Sons, Ltd.	A70
Ryder, Thos., & Son, Ltd.	—
Selson Machine Tool Co. Ltd., The	A85
Servis Recorders, Ltd.	—
Shell-Mex & B.P., Ltd.	A24, A25
Smart & Brown (Machine Tools), Ltd.	A87
Smith, C. & B., Ltd.	A62
Smith, S., & Sons (England), Ltd.	—
Snow & Co. Ltd.	—
Solex (Gauges), Ltd.	A7
Sparcatron	A58
Spencer Gears, Ltd.	—
Stein Atkinson Vickers Hydraulics, Ltd.	A39
Sunbeam Anti-Corrosives, Ltd.	A50
Super Oil Seals & Gaskets, Ltd.	A28
Swift, Geo., & Sons, Ltd.	—
Sykes Machine Tool Co. Ltd., The	—
Sykes, W. E., Ltd.	—
Talbot Tool Co. Ltd., The	A1
Teddington Industrial Equipment, Ltd.	A61
Terry, Herbert, & Sons, Ltd.	—
Town, Frederick, & Sons, Ltd.	A89
Udal, J. P., Ltd.	A90
Unbrako Socket Screw Co. Ltd.	A52
Universal Tools, Ltd.	A60
Vacu-Blast, Ltd.	—
Van Moppes & Sons (Diamond Tools), Ltd.	A91
Varatio-Strateline Gears, Ltd.	—
Vaughan Associates, Ltd.	A67
Wadkin, Ltd.	A78
Wakefield-Dick Industrial Oils, Ltd.	—
Ward, Thos. W., Ltd.	—
Ward, H. W., & Co. Ltd.	A49
Webster & Bennett, Ltd.	A22
West, Allen, & Co. Ltd.	—
Wickman, Ltd.	A40
Wild-Barfield Electrical Furnaces, Ltd.	—
Woodhouse & Mitchell	—
Zeiss, Carl, Jena	A3

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nal

Page
A74
5, A43
Cover
—
—
A48
—
A80
A88
A75
A8
A74
—
A86
A88
A84
—
A64
7, A86
—
A13
—
A70
—
A85
—
4, A25
A87
A62
—
—
A7
A58
—
A39
A50
A28
—
—
A1
A61
—
A89
A90
A52
A60
—
A91
—
A67
A78
—
—
A49
A22
—
A40
—
—
A3

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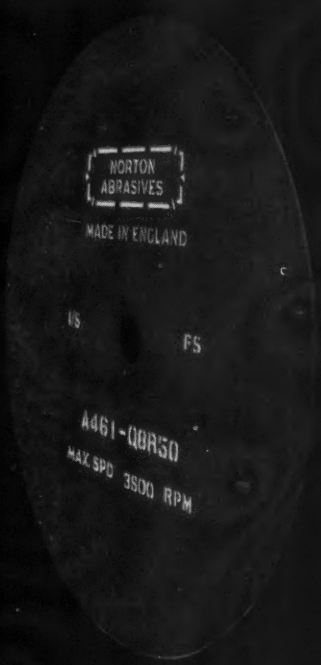

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WELWYN GARDEN CITY, HERTS. Telephone: WELWYN GARDEN 4501 (10 lines)

NORTON ABRASIVES

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